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Morphometric Analysis and Descriptions of Selected Species in the *Encarsia strenua* Group (Hymenoptera: Aphelinidae)

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Abstract.—The *Encarsia strenua* group is defined using three synapomorphies: presence of 1–3 specialized setae at the apex of the costal cell, a bare area above the stigmal vein and closely placed scutellar sensillae. Few morphological characters were found that could accurately distinguish some species of the *strenua* group because of variability within species and the lack of diagnostic differences among species. The morphometric relationships of females of five closely related species of the *strenua* group were explored using bivariate and multivariate statistical methods. Univariate or bivariate measures could not distinguish all groups, however, all five species were discriminated along the first two canonical variates. Host relationships, although having a strong effect on general size, do not affect the discrimination of taxa An identification key is provided for six species of the *strenua* group. *Encarsia citri, E. protransvena* and *E. strenua* are redescribed. Two new species, ***E. bimaculata*** and ***E. neocala,*** are described. ***Encarsia sophia* (Girault & Dodd)** is proposed as a senior synonym of ***E. transvena* (Timberlake).**

The genus *Encarsia* (Hymenoptera: Aphelinidae, Coccophaginae) is a diverse and cosmopolitan group of species usually parasitic on Aleyrodidae (whiteflies), Diaspididae (armored scales), or themselves (as autoparasitoids) (Polaszek 1991). A few species are parasitoids of the eggs of Lepidoptera (Polaszek 1991). At present there are more than 200 described species of *Encarsia* (Polaszek *et al.* 1992), and new species are continually being described or recognized. The genus *Encarsia* represents one of the most important parasitic groups used in biological control, and various species are currently being collected as part of intensive foreign exploration efforts to search for parasites of whiteflies of the genus *Bemisia.* Several species of *Encarsia* have demonstrated their importance for control of San Jose Scale (*E. perniciosi* (Tower)) (Clausen 1978), Greenhouse whitefly (*E. formosa* Gahan) (Clausen 1978), Ash whitefly (*E. inaron* (Walker)) (Bellows et al. 1992), and Spiny blackfly (*E. smithi* (Silvestri)) (Kuwana 1934). New programs are focusing on the control of *Bemisia* with *E. protransvena* Viggiani and *E. sophia* (Girault) and on citrus whitefly in California with *E. variegata* Howard (T. Bellows, pers. comm.). Biological and taxonomic characteristics remain poorly known even for common species of *Encarsia.*

Within *Encarsia,* approximately 29 species groups are recognized by various authors (Viggiani & Mazzone 1979; Hayat 1989; Polaszek *et al.* 1992), with as few as 16 groups in the most recent treatment by Hayat (1998). Few of these groups are recognized by morphological characters and different species may be included in each by various authors. We have rediagnosed the *strenua* species group, which is here recognized by having closely spaced scutellar sensilla (Figs. 5, 20), a group of one to three marginal setae at the apex of the costal cell of the fore wing (Fig. 10, arrow), and a bare area just anterior to the stigmal vein (Fig. 10). The *strenua* group now includes 40 species, more than a third of these previously undescribed.

In this paper we attempt to address problems in the taxonomy of a subset of species, which rank among the more important members of the *strenua* group for the control of economically important whiteflies. Resolution of this complex is necessary before going ahead with an identification key to the 40 recognized species. Morphometric analysis, descriptions and an identification key are presented to express the differences between *E. bimaculata* new species, *E. citri* Ishii (revised status), *E. neocala* new species, *E. protransvena*, and *E. strenua*. One of the most commonly enountered species in agricultural settings, *E. sophia*, can be readily distinguished by discrete morphological attributes from other species in the *strenua* groups, and was not included in the morphometric analyses.

MATERIALS AND METHODS

Morphometric analysis.—In total, 196 females of five species of *Encarsia*, *E. bimaculata* (n = 61), *E. citri* (12), *E. neocala* (15), *E. protransvena* (83) and *E. strenua* (24) were measured. Males are rare or unknown for some species and were not included. Measurements were taken from slide-mounted material (Table 1) amassed from collections at the National Museum of Natural History (USNM), University of California (UCRC), Texas A&M University (TAMU), and Instituto di Entomologia F. Silvestri, Portici, Italy (IEUN). *Encarsia protransvena* were included from multiple locations in various Gulf Coast States (Mississippi, Florida, Georgia), Puerto Rico, Colombia, Spain and the Grand Caymans, and several different host whiteflies: *Bemisia tabaci* (Gennadius), *Dialeurodes citri* (Ashmead), *D. citrifolii* (Morgan), *D. kirkaldii* (Kotinsky), *Parabemisia myricae* (Kuwana), and *Trialeurodes abutiloneus* (Haldeman). *Encarsia neocala* were measured from a single collection from New Caledonia reared from *Orchamoplatus* [probably *caledonicus* (Dumbleton)] (Aleyrodidae). *Encarsia citri* were measured from a single collection in Japan from *D. citri*. *Encarsia bimaculata* were sampled from the Oriental Region (Hong Kong, India, Philippines, Thailand) and the Nearctic Region (Florida, Texas) and reared only from *B. tabaci*. Most specimens were mounted in Hoyer's medium, although a few were mounted in Canada Balsam. Measurements of type material were included for *E. strenua*, *E. bimaculata* and *E. protransvena*. The type material of *E. protransvena* is distorted, with measurements of the ovipositor most affected. Although this distortion greatly affected the univariate statistics, and hence their separation in the identification key, there was no overall affect on the placement of these specimens in the discriminant analyses. Measurements of the holotype of *E. armata* were initially included but they were very distinct from the other material and the data were removed from further analyses to prevent a general distortion of the results from the single specimen. Specimens were chosen that could be measured for all of the values so that missing values were not a part of the data set.

Size and shape differences were characterized by choosing 16 landmark points (black dots, Fig. 1) on the fore wing (1A, 5 points), gaster (1B, 3 points), mid tibia (1C, 2 points) and antenna (1D, 6 points). Measures of the apex of the fore wing could not be associated with specific structures and points were chosen by estimating the most apical point of the fore wing (FWL) and the greatest distance perpendicular to the anterior margin of the fore wing (FWW). The 10 measures (Fig. 1, Table 2) were selected as being appropriate for separating these and other species of *Encarsia*.

Specimens were measured using a Leica DMRB microscope at 78.8 × magnification. Point measures were taken using Morphosys (Meachum & Duncan 1987) through a Sony DXC-107 videochip camera. Reference coordinates were collected and converted to euclidean distances in

Table 1. *Encarsia* species and associated geographic and biological information used in the morphometric analysis. The host list is complete for the material available. Additional host records for *E. protransvena* include *Trialeurodes variabilis* on *Carica* (Caricaceae) and *Aspidiotus* on *Dioscorea* (probably erroneous). Questionable localities (possibly contaminated laboratory cultures) are marked by a double question mark.

Encarsia	Locality	n	Host species	Plant host
E. bimaculata	Hong Kong	2	*Bemisia tabaci*	*Hibiscus* (Malvaceae)
	India	3	*Bemisia tabaci*	*Hibiscus*
	India	25	*Bemisia tabaci*	culture
	Israel ??	5	*Bemisia tabaci*	culture
	Mexico ??	1	*Bemisia tabaci*	*Hibiscus*
	Philippines	13	*Bemisia tabaci*	*Solanum* (Solanaceae)
	Sudan ??	1	*Bemisia tabaci*	culture
	USA: Florida	3	*Bemisia tabaci*	*Hibiscus*
	USA: Florida	3	*Bemisia tabaci*	*Sesamum* (Pedaliaceae)
	USA: Florida	2	*Bemisia tabaci*	*Euphorbia* (Euphorbiaceae)
	USA: Texas	5	*Bemisia tabaci*	culture
E. citri	Japan	12	*Dialeurodes citri*	*Citrus* (Rutaceae)
E. neocala	New Caledonia	15	*Orchamplatus* sp.	*Citrus*
E. protransvena	Colombia ??	2	*Dialeurodes citrifolii*	*Citrus*
	Grand Cayman	2	*Dialeurodes citrifolii*	*Citrus*
	USA: Florida	1	black whitefly	*Liquidambar* (Hamamelidaceae)
	USA: Florida	2	*Dialeurodes citri*	*Ligustrum* (Oleaceae)
	USA: Florida	5	*Dialeurodes citri*	*Melia* (Meliacae)
	USA: Florida	3	*Dialeurodes citri*	*Citrus*
	USA: Florida	21	*Dialeurodes citrifolii*	*Dioscorea* (Dioscoreaceae)
	USA: Florida	3	*Dialeurodes citrifolii*	*Citrus*
	USA: Florida	3	*Dialeurodes kirkaldii*	*Jasminum* (Oleaceae)
	USA: Florida	1	*Dialeurodes* sp.	*Jasminum*
	USA: Florida	1	*Trialeurodes abutilonia*	*Solanum* (Solanaceae)
	USA: Georgia	4	*Dialeurodes citri*	*Jasminium*
	USA: Georgia	3	*Bemisia tabaci*	*Gossypium* (Malvaceae)
	USA: Georgia	4	*Bemisia tabaci*	*Hibiscus*
	USA: Mississippi	1	*Bemisia argentifolia*	*Abelmoschus* (Malvaceae)
	USA: Mississippi	3	*Bemisia argentifolia*	*Cleome* (Capparaceae)
	Puerto Rico	19	*Dialeurodes citrifolii*	*Citrus*
	Puerto Rico	1	*Dialeurodes citri*	*Citrus*
	Puerto Rico	1	*Parlatoria ziziphi**	*Citrus*
	Spain	2	*Parabemisia myricae*	unknown
E. strenua	China: Guangzhou	1	*Dialeurodes* sp.	*Citrus*
	Hong Kong	2	*Dialeurodes kirkaldii*	*Jasminium*
	Hong Kong	1	*Bemisia giffardii* (HT)	unknown
	India	15	*Dialeurodes citri*	*Citrus*
	USA: California	5	*Parabemisia myricae*	*Citrus*

* Probably a wrong association (Diaspididae).

Morphosys, and analyzed using the statistical analysis system (SAS, Version 6.12) software. Principle component analysis (PCA) was performed on the variance-covariance matrix for the 10 variables formed from the logarithms (base 10) of the raw data. PCA was performed to observe the distribution of observations without the *a priori* constraints of assigning them to a particular species (class). Canonical variates analysis (CVA) was used to evaluate variables for the discrimination of individuals using the five species as class variables in the analysis. In all cas-

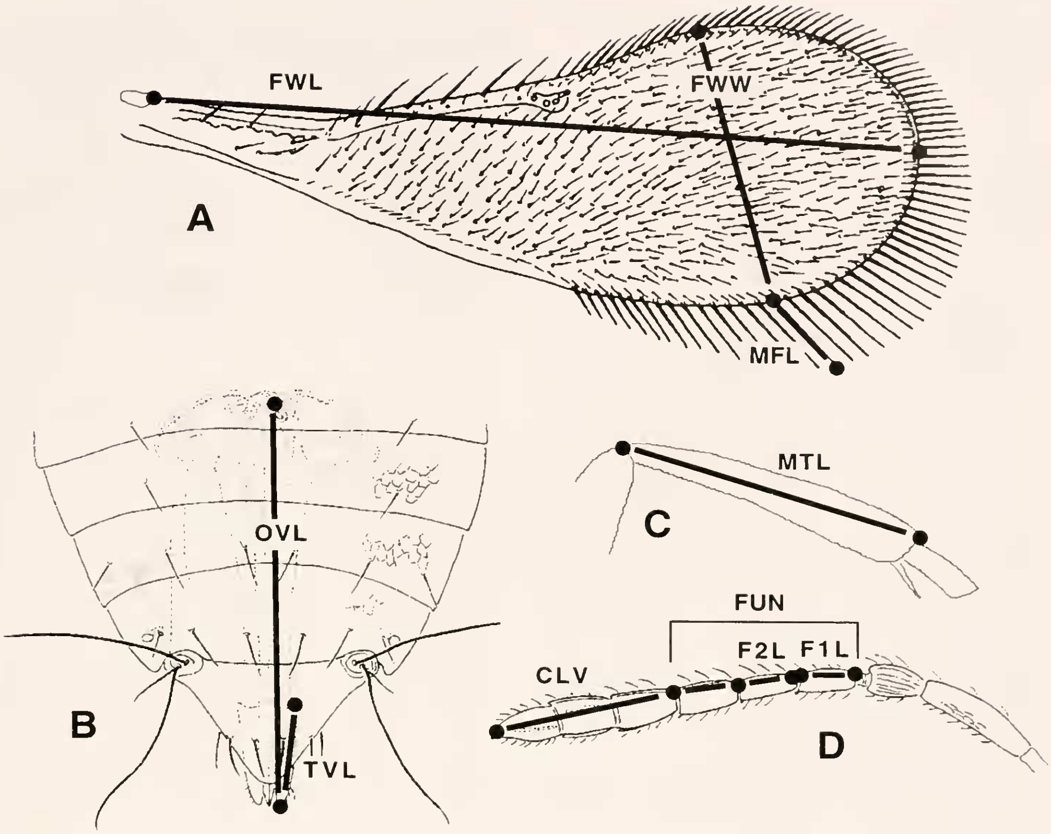


Fig. 1. Measurements of female *Encarsia* for morphometric analysis. Dots are landmark points, the coordinates of which were recorded in Morphosys; heavy lines are calculated distances. (A) fore wing, (B) gaster, (C) mid tibia, (D) antenna.

es, analysis of the raw data was virtually the same as the log-transformed data but only the latter is presented. Homogeneity of the covariance matrices of the five classes was rejected ($P < 0.0001$, $\chi^2 = 405.05$, 220 df); therefore within class rather than pooled covariance matrices were used. The data sets and a list of locality and host

Table 2. Description of distances measured for morphometric analyses.

Abbreviation	Character	Description
FWL	Fore wing length	Maximum length from apex of humeral plate to wing apex.
FWW	Fore wing width	Maximum width measured perpendicular to fore wing margin.
MFL	Marginal fringe length	Length of fringe seta at posterior wing margin.
OVL	Ovipositor length	Length from proximal margin of basal ring to extreme apex.
TVL	Third valvula length	Maximum lateral length.
MTL	Metatibial length	Maximum dorsal length.
CLV	Clava length	Maximum dorsal length.
FUN	Funicle length	Maximum dorsal length (excluding anellus).
F1L	Flagellomere 1 length	Maximum dorsal length.
F2L	Flagellomere 2 length	Maximum dorsal length.

information is available from the authors upon request.

RESULTS

Two distinct clusters of species were apparent from our initial observations of specimens, although these can be difficult to separate on the basis of one or even a few absolute characteristics. *Encarsia strenua* and *E. neocala* have a proportionally longer ovipositor in relation to body size than do *E. bimaculata*, *E. citri* and *E. protransvena*. Although this characteristic is usually distinct, a number of specimens fall into a gray zone in which making an accurate decision is difficult. Within each cluster, species are also difficult to separate because of few clearly defined or absolute characteristics. *Encarsia protransvena* and *E. citri* have been considered as the same species in the past (Polaszek *et al.* 1992), but characteristics of the third valvula (angulate with a prominent lateral seta in *E. citri*) suggest they are distinct species, but again, no single measurement or ratio provides absolute separation of all individuals. Females of *Encarsia bimaculata* are easily distinguished from other species in the analysis by their predominantly dark color (usually a feature of males) and much shorter ovipositor to clava ratio (1.33–1.78 versus greater than 2.0 in the other species), but otherwise they are very similar to *E. protransvena*.

The host ranges for each *Encarsia* species vary from very specific to polyphagous (Table 1). For *E. citri* and *E. neocala*, host specificity may be a product of geographic isolation and limited host availability. For example, a laboratory culture of *E. citri* has been reared successfully for a few years on *Bemisia argentifolii* Bellows & Perring (Bellows, pers. comm.; cultures verified by Heraty & Polaszek). However, *Encarsia bimaculata* has a broad geographic host range and has been reared only from one (*B. argentifolii*, but possibly also *B. tabaci*) species of *Bemisia* (Table 1). Both *E. bimaculata* and *E. protransvena* are sympatric and usually occur in different hosts (*Bemisia* versus *Dialeurodes*), although both have been reared from *Bemisia*. Some species are polyphagous. *Encarsia protransvena* were reared from seven different host species in four genera, and in many cases, were reared from different host species at the same locality. The two specimens of *E. protransvena* reared from *Parabemisia* in Spain represent a substantial departure in both host and range, but these specimens clustered for all of the following measurements and comparisons with other *E. protransvena*. Interestingly, it had been a single odd specimen, a dark female of *Encarsia transvena* from Florida (females normally completely yellow), that had raised our initial suspicions about whether *E. bimaculata* was merely a dark form of *E. protransvena*, and prompted this study.

Univariate and Bivariate Analysis.—Univariate measures, along any particular axis, are either overlapping or very marginally separate species (Table 3), exemplifying the problems associated with separating species by individual measures. Although certain species can be clearly separated, there is a narrow zone of overlap, at least in size, for the pairs of species we would consider as closely related (*E. neocala* and *E. strenua*, *E. protransvena* and *E. citri*). Of the two groups initially recognized (*E. bimaculata*, *E. citri* and *E. protransvena* versus *E. strenua* and *E. neocala*), the ratio of ovipositor length to mid tibial length (OVL/MTL) is probably the best means of separation (Table 4). The overlap in the range of OVL/MTL for *E. protransvena* with *E. strenua* and *E. protransvena* is primarily the result of distortions in the type material; only one paratype specimen exceeds a ratio of 1.58, and only five specimens, including the two paratypes, exceed a ratio of 1.55, which is less than any of the *E. strenua* or *E. neocala*. No other measures by themselves distinguished the two groups. Since not all specimens can be mounted perfectly, any separation based only an OVL/MTL ratio of more or less

Table 3. Univariate statistics for variables in the morphometric analyses of *Encarsia* data set. Variables are means (standard deviation) over range in millimeters.

Variable	*bimaculata*	*protransvena*	*citri*	*strenua*	*neocala*
n	61	83	12	24	15
FWL	0.48 (0.04) 0.34–0.54	0.60 (0.07) 0.48–0.75	0.77 (0.06) 0.65–0.85	0.73 (0.70) 0.61–0.82	0.55 (0.04) 0.50–0.63
FWW	0.16 (0.02) 0.12–0.20	0.21 (0.03) 0.16–0.28	0.31 (0.02) 0.26–0.35	0.28 (0.03) 0.02–0.33	0.23 (0.02) 0.21–0.27
MFL	0.07 (0.01) 0.06–0.08	0.06 (0.01) 0.05–0.07	0.07 (0.01) 0.06–0.08	0.06 (0.01) 0.04–0.07	0.05 (0.01) 0.04–0.06
OVL	0.02 (0.02) 0.15–0.23	0.30 (0.03) 0.22–0.37	0.34 (0.02) 0.28–0.36	0.47 (0.05) 0.35–0.55	0.30 (0.03) 0.27–0.34
TVL	0.06 (0.00) 0.05–0.07	0.08 (0.01) 0.05–0.11	0.09 (0.01) 0.08–0.10	0.14 (0.02) 0.11–0.16	0.10 (0.01) 0.08–0.12
MTL	0.16 (0.01) 0.12–0.18	0.21 (0.03) 0.16–0.27	0.26 (0.02) 0.22–0.28	0.27 (0.03) 0.21–0.32	0.18 (0.02) 0.16–0.21
CLV	0.13 (0.01) 0.10–0.15	0.13 (0.01) 0.09–0.15	0.16 (0.01) 0.14–0.17	0.16 (0.01) 0.13–0.17	0.13 (0.01) 0.12–0.14
FUN	0.12 (0.01) 0.08–0.14	0.14 (0.02) 0.10–0.17	0.19 (0.01) 0.17–0.21	0.18 (0.02) 0.15–0.20	0.12 (0.01) 0.10–0.14
FIL	0.04 (0.00) 0.03–0.05	0.05 (0.01) 0.03–0.06	0.06 (0.01) 0.05–0.07	0.06 (0.01) 0.04–0.07	0.04 (0.01) 0.03–0.05
F2L	0.04 (0.01) 0.02–0.05	0.05 (0.01) 0.03–0.06	0.07 (0.00) 0.02–0.05	0.06 (0.01) 0.04–0.06	0.04 (0.01) 0.03–0.05

than 1.55 may fail and other measures or characteristics are necessary.

Through combinations of variables, more distinctive nonoverlapping differences occur. *Encarsia bimaculata* are distinct from *E. citri* in all bivariate plots (Fig. 2). *Encarsia protransvena* show some overlap with *E. bimaculata* and *E. citri* in most plots, with *E. citri* most distinct for OVL/CLV (Fig. 2B), OVL/FUN (Fig. 2C) and TVL/FUN (Fig. 2D) and *E. bimaculata* most distinct for OVL/CLV (Fig. 2B) and OVL/FUN (Fig. 2C). In no case is there a clear, non-overlapping, separation of these species based on either univariate statistics (Table 2) or, with the exception of OVL/CLV for *E. bimaculata,* the ratios formed by each of these combinations (Table 4). The noticeable overlap between *E. neocala* and *E. protransvena* for some characters (Figs. 2: B, C) can be dismissed by other more distinctive morphological characteristics (dark pronotum, broader fore wing, longer ovipositor). *Encarsia neo-*

Table 4. Range of ratio measures for the combinations of features represented in Figure 1.

Ratio	*bimaculata*	*protransvena*	*citri*	*strenua*	*neocala*
FWL/FWW	2.58–2.99	2.62–3.11	2.39–2.68	2.44–2.67	2.32–2.44
OVL/CLV	1.33–1.78	2.00–3.37	2.00–2.34	2.43–3.26	2.16–2.56
OVL/FUN	1.52–1.94	1.85–2.85	1.63–2.01	2.35–2.89	2.39–2.76
TVL/FUN	0.43–0.59	0.40–0.79	0.42–0.54	0.70–0.89	0.72–0.98
TVL/OVL	0.25–0.36	0.19–0.32	0.24–0.30	0.27–0.34	0.29–0.38
OVL/MTL	1.09–1.38	1.29–1.74	1.22–1.35	1.56–1.97	1.60–1.79

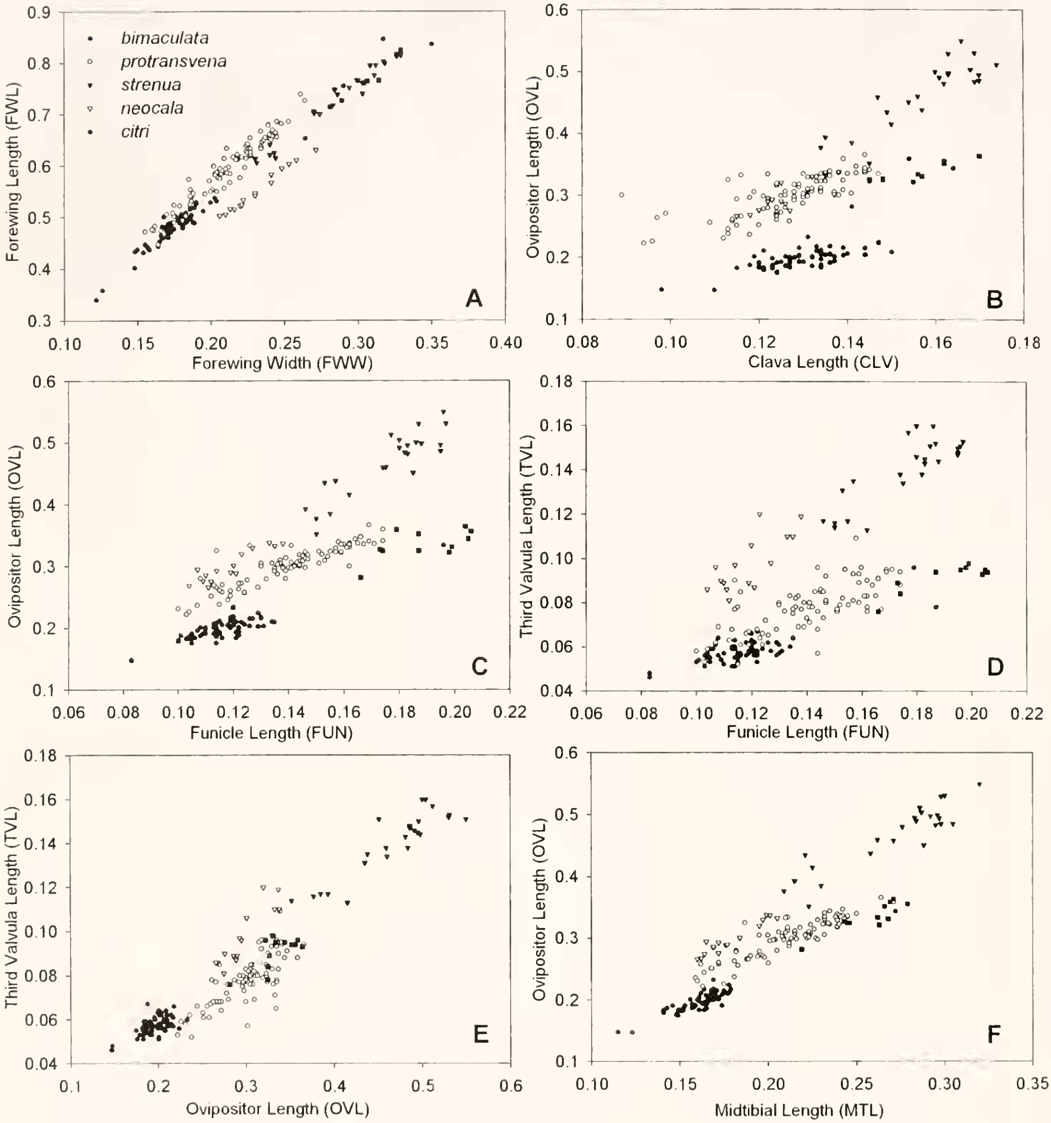


Fig. 2. Two-variable scatterplots for the five species of *Encarsia*. All measurements in mm.

cala and *E. strenua* are clearly separated from each other on all of the bivariate plots (Fig. 2), although for ratio comparisons, they are distinct, but overlapping, only for FWL/FWW (Table 4). In all cases, the five specimens of *E. strenua* reared from *Parabemisia* in California were smallest in size for most characteristics, usually forming a distinct cluster isolated from the majority of the southeast asian *E. strenua* (Fig. 2).

Bivariate plots of the variables which best discriminate the species of *Encarsia* (Fig. 2), in general, demonstrate a strong positive correlation based on size. Fore wing length and width (Fig. 2A) have the most direct linear association. Size variation of the host whiteflies does appear to have an effect on parasitoid size: *Bemisia* consistently yielded the smallest parasitoids (*E. bimaculata* and *E. protransvena*), *Parabemisia* yielded moderately-sized wasps

(*E. protransvena* and *E. strenua*), and *Orchamoplatus* yielded intermediate sized wasps (*neocala*). *Dialeurodes,* however, yielded almost the entire range of sizes found in *E. citri, E. protransvena* and *E. strenua.* Within *Dialeurodes, D. citri* and *D. kirkaldii* yielded the complete range of size variants for both *E. protransvena* and *E. strenua; E. protransvena* reared from *D. citrifolii* had a similar range of size variants, but only within the bounds of that species.

Principal Components Analysis.—Individual specimens of the five species are projected on the first two principal components, which accounted for 92.6% of the overall variance (Fig. 3). The first principal component (PCI) accounts for 84.4% of the variance. Even with log-transformed data, size has an obvious impact on the distribution of points along PCI with the smallest species, *E. bimaculata,* having strong negative values along PCI and the larger species, *E. citri* and *E. strenua,* having strong positive values along PCI. Eigenvalues and weights for the first two components are presented in Table 5. Marginal fringe length (MFL) had almost no contribution to PCI. This absence of any correlation was reflected in a bivariate plot of MFL against FWL, which showed almost no correlation within species; a rather surprising result considering the importance of the relative length of the MFL in *Encarsia* taxonomy. Along PCI, the other variables had approximately equal contributions, although measurements of the ovipositor (OVL, TVL) had the largest influence. Along PCII, the marginal fringe (MFL), ovipositor (OVL, TVL) and antenna (FUN, F1L, F2L) had the greatest influence.

Five distinct clusters, representing the five species, occur within the first two principal components of the log-transformed data (Fig. 3). *Encarsia protransvena* had the greatest scatter of points and overlaps minimally with *E. neocala, E. bimaculata* and *E. citri,* but not at all with *E. strenua.* Considering that there are no *a priori* assumptions of group membership, we regard the clustering of points as a strong indicator of their group membership. Each overlapping group was clearly distinguished on examination of the third principal component.

A principal components analysis of only *E. protransvena,* using either host or locality as *a priori* groups, failed to separate out any meaningful clusters along the first three principal components.

Canonical Variates Analysis.—Individual specimens are projected along the first two canonical variates (CVI & CVII) of the log-transformed data, which account for 89.3% of the original variance (Fig. 4). The five species are clearly discriminated, however no species can be completely separated along the first canonical variate and only *E. neocala* can be clearly separated along the second. Although *E. citri* appears to overlap with *E. bimaculata* and *E. protransvena,* it is very clearly discriminated on a projection of the second and third canonical variate. The points for *E. citri* are in a plane clearly behind (class mean of −4.32 along CVIII; Table 6) those of *E. bimaculata* ($\bar{x}$ = 0.88) and *E. protransvena* ($\bar{x}$ = −0.37). The single specimen of *E. bimaculata* that appears to overlap the *E. citri* cluster along CVI and CVII is part of a long series reared from *Bemisia* in India. This specimen has a longer ovipositor (0.233 mm) than other *E. bimaculata* but, although it is an outlier on all of the bivariate plots, it is not distinct from the main cluster and is never included in the *E. citri* group in the univariate comparisons (Fig. 2). Also, the score for the specimen along CVIII (1.34) is about average from other *E. bimaculata* and very distinct from *E. citri* (−4.98 to −3.52). *Encarsia protransvena* and *E. citri,* which are difficult to separate on univariate characteristics, very marginally overlap on CVI & CVII; the clusters for each are distinct along CVII & CVIII, but with an overlap of scores along each variate. Notably, *E. strenua* and *E. neocala* are clearly separated on both CVI

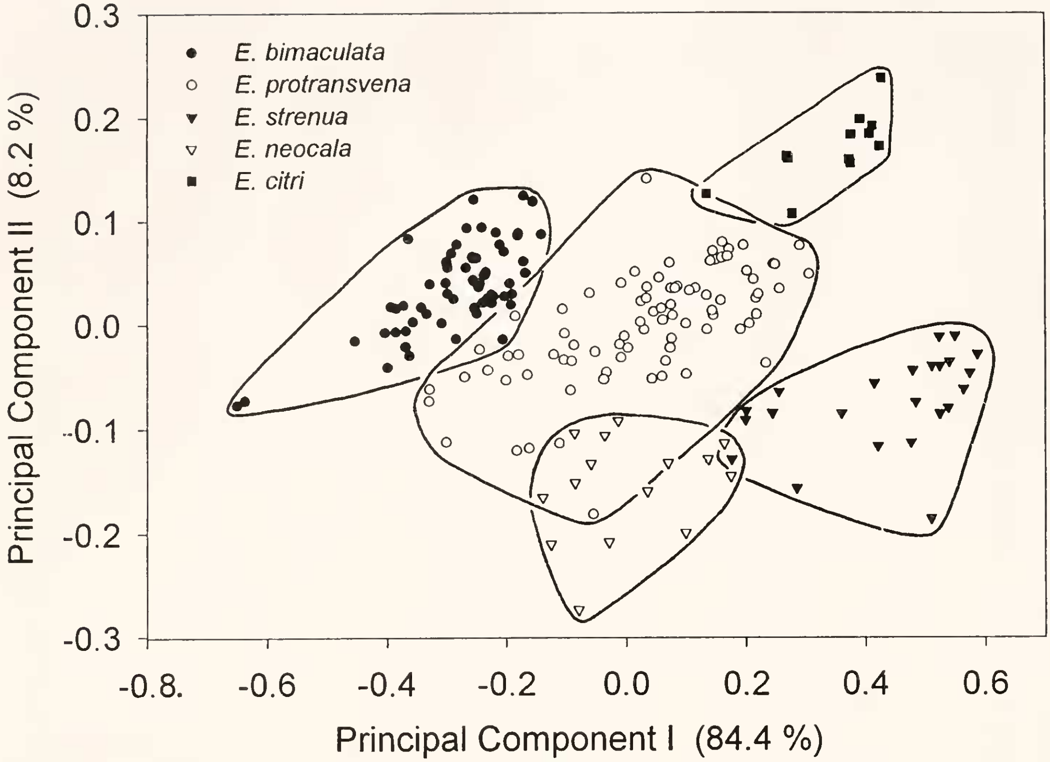


Fig. 3. Plot of the first two principal components from the principal components analysis of the log-transformed data set. The first principal component contains 84.4% of the sample variance, the second principal component contains 8.2%. Artificial boundaries define the limits of *a priori* groups.

& CVII (Fig. 4) and CVII & CVIII, with the majority of separation in both cases occurring along CVII (Table 6). A reclassification of individuals using the discriminant functions resulted in 100% allocation to the correct *a priori* grouping. Stepwise discriminant analysis failed to identify any variables that could be excluded and still provide accurate classification of all specimens.

Table 5. Eigenvalues and weights for the first two principal components, computed from the covariance matrix of the log-transformed data.

Variable	PCI	PCII
Eigenvalue	0.073	0.007
Proportion of Variance	0.844	0.082
FWL	0.28	0.14
FWW	0.32	0.09
MFL	−0.06	0.46
OVL	0.45	−0.34
TVL	0.44	−0.55
MTL	0.32	0.11
CLV	0.14	0.16
FUN	0.30	0.29
F1L	0.33	0.30
F2L	0.31	0.37

The standardized and raw coefficients for the log-transformed data are presented in Table 6. The standardized coefficients represent the amount that the canonical variate will change for each change in the original variable by one standard deviation (Woolley & Browning 1987). Larger coefficients are generally better characters for discriminating points along that particular analysis. Characteristics of the ovipositor (OVL) and fore wing (FWL, FWW) had the strongest contribution along the first variate (CVI). These were also ranked as the best variables for discrimination in

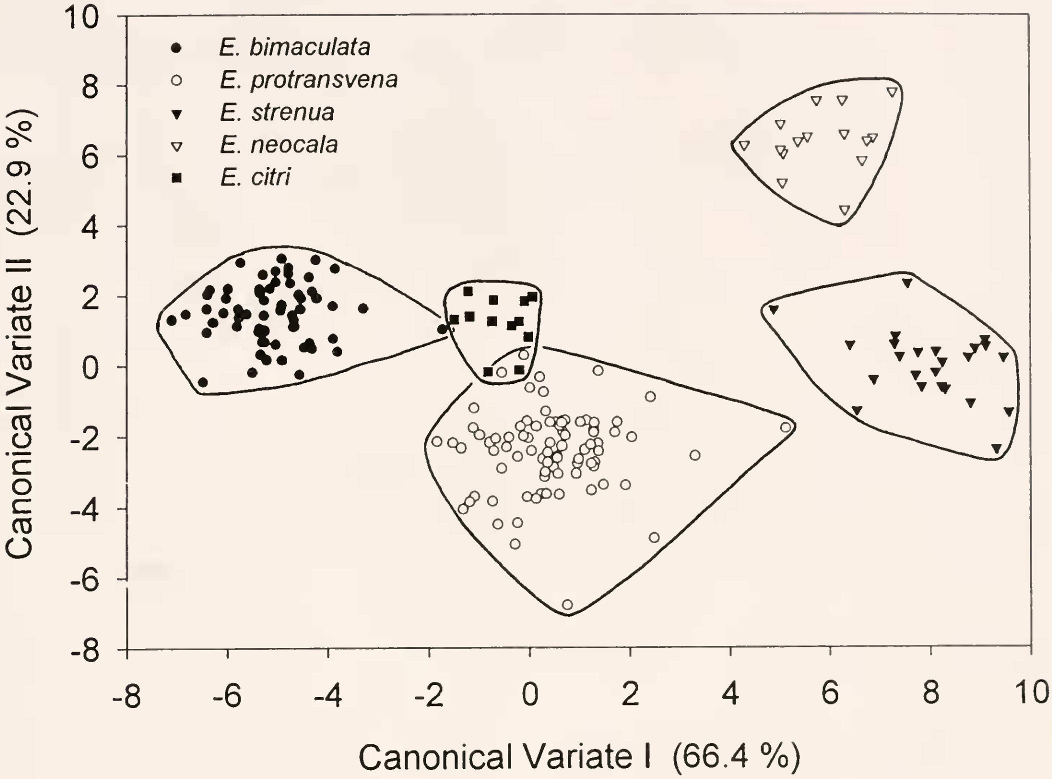


Fig. 4. Plot of the first two canonical variates from the canonical variates analysis of the log-transformed data set. The first canonical variate contains 66.4% of the sample variance, the second canonical variate contains 22.9%. Artificial boundaries define the limits of *a priori* groups.

the stepwise analysis. Of the two most substantial features, *E. strenua* and *E. neocala* have a proportionally longer ovipositor, as already noticed, and *E. bimaculata* has a proportionally shorter fore wing. Length of the metatibia (MTL) and, again, the fore wing (FWL, FWW) were strong contributors to the second canonical variate.

A canonical variates analysis of only *E. protransvena*, using either host or locality as reference criteria, failed to separate out any meaningful clusters in different ordinations of the first three canonical variates. The only segregation using host as a class criterion was along the first canonical variate, with individuals reared from *Bemisia* mostly negative (canonical scores below 0) and individuals from all of the other whitefly species mostly positive (scores greater than −1). *Bemisia* are smaller than the other whiteflies, and this likely represents segregation by size. Using geographical locality as the class criterion, there was no meaningful segregation of clusters by locality along any axes; the only segregation of clusters was again host related, corresponding to species reared from *Bemisia* versus other whiteflies along the first canonical variate. The error rate for reclassifying the observations was 23.9% for all observations and 56.4% for specimens from Florida (n = 39).

DISCUSSION

Our initial grouping of species is supported by the distinct clustering of groups found using either principal components or canonical variates analysis. Most of the specimens were segregated along the first

Table 6. Standardized and raw coefficients and class means for the canonical variates analysis. The rows have been sorted by the elements of the vector of standardized coefficients for the first canonical variable. Standardized coefficients are the amount that the canonical structure will change for a change in the original variable of one standard deviation.

Variable	Standardized coefficients			Raw coefficients		
	CV1	CV2	CV3	CV1	CV2	CV3
OVL	5.91	−1.88	0.36	46.81	−14.85	2.86
FWW	2.88	6.02	−1.53	31.64	66.04	−16.83
TVL	1.11	1.85	1.08	8.55	14.16	8.26
F1L	0.74	0.10	−0.62	0.77	1.09	−6.42
MFL	−0.01	−0.18	0.12	−0.21	−3.24	2.15
F2L	−0.28	0.10	−1.84	−3.03	1.12	−19.99
CLV	−0.57	0.68	1.19	−11.18	13.46	23.54
FUN	−0.75	−0.80	1.52	−8.79	−9.44	17.86
MTL	−1.40	−3.75	3.06	−15.59	−41.62	33.98
FWL	−3.31	−2.65	−3.42	−42.56	−34.06	−44.04
Species	Class means					
bimaculata	−5.08	1.49	0.88			
protransvena	0.45	−2.43	−0.37			
citri	−0.57	1.20	−4.32			
strenua	7.98	0.02	1.79			
neocala	5.84	6.39	−0.96			

two axes in both analyses, and any area of overlap was resolved along the third axis. The fact that all specimens could be correctly reclassified to their respective *a priori* groups is another indication of their distinctness. The complexity of the separation is, however, reflected by the inability to remove any of the variables to achieve complete reclassification.

Encarsia bimaculata is the most distinctive species in both color and morphology, and none of the analyses would support these as mere color variants of *E. protransvena*. Both *E. bimaculata* and *E. protransvena* are parasites of *Bemisia tabaci/argentifolii* in the same geographical region, and yet both maintain their morphometric integrity. *Encarsia citri* can be separated from *E. protransvena* by the structure of the third valvula and setae of the midlobe. These characters are subtle and may not be trustworthy. However, *E. citri* formed a morphometric grouping distinct from *E. protransvena* in all analyses. Again, both species use *D. citri* as a host but, even when using the same host, *E. citri* were consistently larger in size for almost all features except ovipositor length. The separation of *E. citri* from *E. protransvena* in the morphometric analyses was along all three axes, suggesting that both size and shape contributed to the difference.

Encarsia protransvena were most variable for both size and host range. Hosts, which vary in size, have an obvious impact on size of the parasitoids. Specimens of *E. protransvena* reared from *Bemisia* were generally smaller for most features than those reared from other hosts. In the canonical variates analysis by host, the specimens reared from *Bemisia* were separated along the first axis, with highest weights applied to the length and width of the fore wing (shorter and broader in specimens reared from *Bemisia*), although this was barely noticeable in the bivariate plots and is here considered as inconsequential. The full range of size, from smallest to largest were found in specimens reared from *Dialeurodes*, and among these, *D. citri* yielded the largest size range. Whether the size range from *D. citri* is a result of parasitoids emerging from different sized host or different instars is unknown.

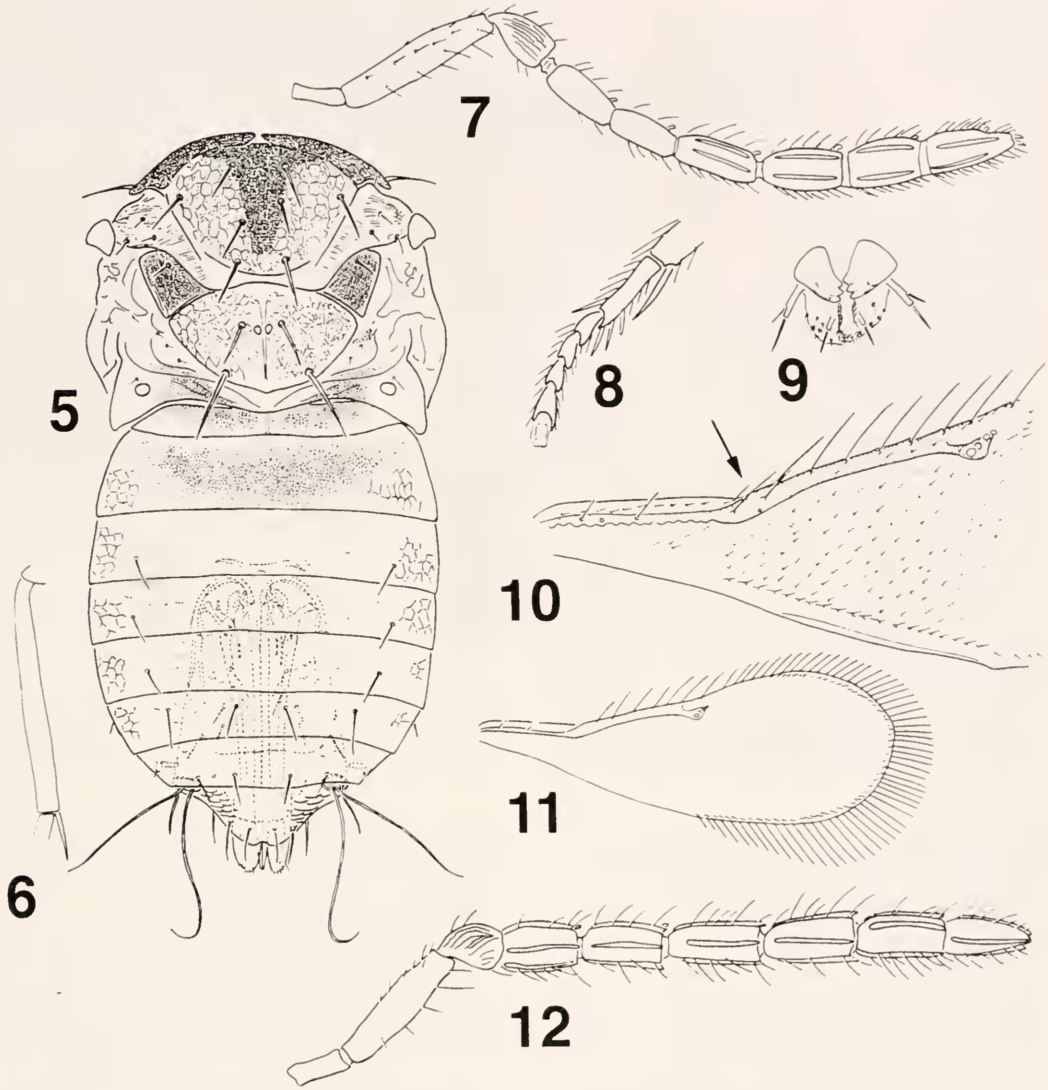
Encarsia bimaculata, E. citri, E. neocala and *E. strenua* all have a southeast Asian origin. *Encarsia bimaculata* was purposefully introduced into Florida from India (Nguyen & Bennett 1995). *Encarsia strenua* was probably introduced into California from original material collected in India. Although material of *E. strenua* from India was reared in quarantine in Riverside, CA, in 1969, there is no record of a purposeful release of this species. The californian *E. strenua* was collected only between 1980 and 1982 at Tustin and the Irvine Ranch, both in Orange County, California. The origin of *E. protransvena* in the New World is more puzzling, especially as only two of the 40 species that we place in the *strenua* group are apparently endemic in the New World. *Encarsia protransvena* has been recorded primarily from the gulf coast states (Florida through Texas) and Puerto Rico, and from single rearings in Grand Cayman, Colombia (*D. citrifolii*), California (*D. citri*), and Honduras (*B. tabaci*) (Polaszek *et al.* 1992). The records from Central and South America and Grand Cayman all appear to be valid rearings from field collected material. The single record from California is probably from release efforts being undertaken at that time (Bellows, pers. comm.). For all of the bivariate and multivariate analyses, these odd rearings of *E. protransvena* clustered within the main group of specimens and are indistinguishable by any set of measurements from other *E. protransvena*. *Bemisia* and both species of *Dialeurodes* have been known from Florida since the early 1900's (Mound 1978; Nguyen *et al.* 1993), and yet no members of the *strenua* group were reared from whiteflies in any of these countries prior to 1984 (collection date of type material), even though there are several earlier collections of other species of *Encarsia* from whiteflies in Florida (Nguyen *et al.* 1993) and despite a renewed research program focusing on the parasitoids of *Dialeurodes* in the late 1970's (Nguyen and Sailer 1979; Sailer *et al.* 1984). A collection of three specimens reared from *Parabemisia* in Valencia, Spain (included in the morphemetric analyses), three specimens from China and Taiwan reared from *Dialeurodes* and *Aleurotrachelus* (Huang & Polaszek 1998), and one female from Egypt reared from *Dialeurodes* (Polaszek *et al.* 1999) are the only collections of *E. protransvena* from the Old World. Although from a unique host, the two specimens from Spain were certainly not unique morphologically and were about average (clustering centrally) for all bivariate and multivariate comparisons. The Egyptian specimen agrees in all characters with *E. protransvena*. The specimens from China and Taiwan were not part of this analysis, but exhibit diagnostic differences (see comments after description of *E. protransvena*) from the New World and Spain material that might suggest they could be a different species close to *E. protransvena* or *E. citri*. If *E. protransvena* did have an eastern Palearctic or southeast Asian origin, we expect that it would be more widespread as it is in the New World. However, the distribution and success of *E. protransvena* cannot be used to demonstrate its origin, and the evidence remains equivocal over the origin of *E. protransvena* in the southeastern United States as to whether it was accidentally introduced from the Old World (western Palearctic or southeast Asia) and became abundant in its new habitat, or if it spread northward from an origin in South America or the Carribean. It might be interesting to postulate that the appearance of *E. protransvena* coincides with the apparent replacement of *Bemisia tabaci* with *B. argentifolii*, but the parasitoid also was found to be common on other genera of whiteflies in the same geographical range.

A discriminant function may be the best means of separating species such as *E. protransvena* and *E. citri*. However, in all cases, a majority of specimens can be successfully keyed using relatively straightforward measurements having a minimal amount of overlap, and any specimens within the zone of overlap can be segregated using other characters which may apply only to these specimens but not to all of the specimens. Although still creating complex couplets, we feel that this would be the best means to painlessly separate species and is the method used in the accompanying identification key.

KEY TO FEMALES OF COMMONLY ENCOUNTERED SPECIES OF THE *STRENUA* GROUP

This identification key refers only to the species dealt with in this paper, a small representation of the 40 species that we have recently examined. It will, however, work for the species most commonly encountered in economically important crops. Members of the *strenua* group are recognized by having a combination of 2–3 marginal setae along the dorsal margin of the costal cell at the apex, a bare area just above the stigmal vein, and scutellar sensillae closely placed or touching.

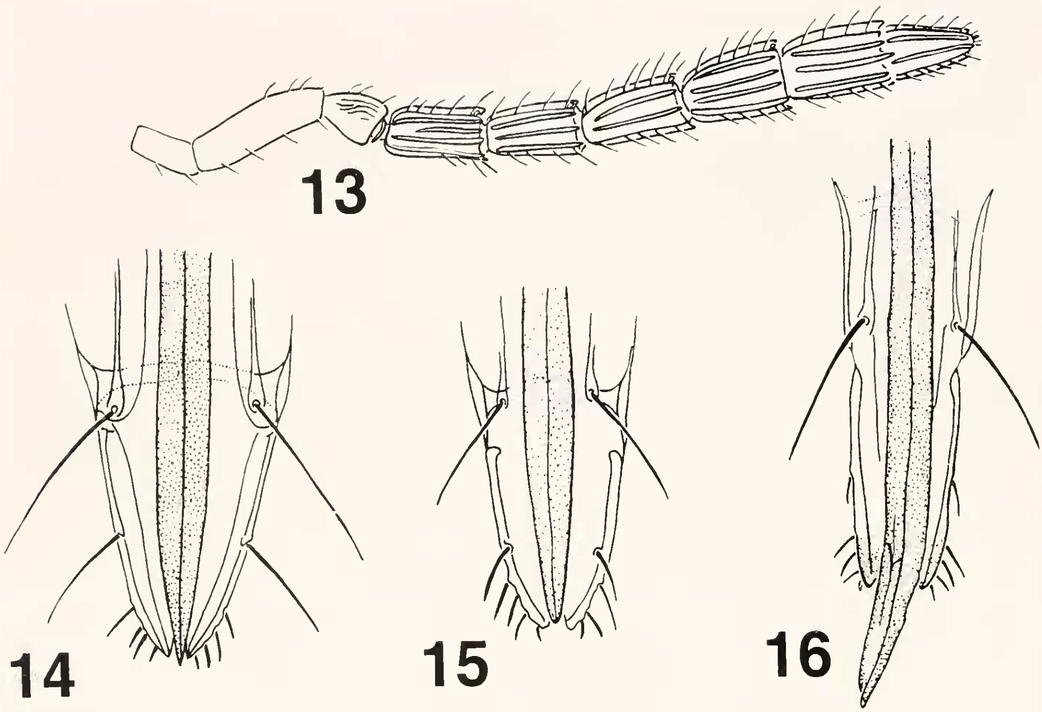
1. Ovipositor almost as long as gaster, more than 1.56 times as long as middle tibia, if between 1.5 and 1.65 times then fore wing less than 2.6 times as long as broad. Ovipositor robust, tip often bent at an angle in slide-mounted specimens 2
– Ovipositor clearly shorter than length of gaster, less than 1.5 times as long as middle tibia, some *E. protransvena* 1.5–1.6 times [deformed holotype 1.74 times], but then fore wing more than 2.67 times as long as broad [2.9 times in holotype of *E. protransvena*]. Ovipositor slender, tip always straight. 3
2. Third valvula entirely yellow. Fore wing less than 2.44 times as long as broad and ovipositor less than 2.6 times as long as clava . . . . ***E. neocala* Heraty and Polaszek, n. sp.**
– Third valvula dark brown at the extreme tip, otherwise yellow (Fig. 16). Fore wing more than 2.44 times as long as broad and ovipositor usually more than 2.7 times as long as clava, if shorter then fore wing more than 2.5 times as long as broad . . . ***E. strenua* (Silvestri)**
3. Metasomal tergite 7 (tergite with spiracles) with 4 setae, only 2 long setae medial to cerci (Fig. 29); ocellar triangle irregularly aciculate . . . . ***E. sophia* (Girault) (= *transvena*)**
– Mt7 with 6 setae, 4 long setae medial to cerci (Fig. 27); ocellar triangle usually reticulate, if aciculate then with a different pattern [not all species included in this key] 4
4. Body with extensive dark pigmentation (at least a large part of the mesoscutum, or two or more gastral tergites, dark) (Fig 5). Ovipositor less than 1.8 times as long as clava . . . . ***E. bimaculata* Heraty and Polaszek n. sp.**
– Body, including antennae, almost entirely yellow. Ovipositor more than 2.0 times as long as clava 5
5. Basal seta of third valvula long, exceeding base of subapical seta; subapical seta located half way between basal seta of third valvula and apex (Fig. 14). Midlobe of mesosoma usually with 5 pairs of setae, preapical pair overlapping or exceeding base of apical pair. Fore wing usually less than 2.6 times as long as broad (83.3% of specimens examined), if between 2.6 and 2.7 times, then clava more than 0.14 mm in length . . . . ***E. citri* Ishii**
– Basal seta of third valvula not reaching base of subapical seta; subapical seta located beyond half way (0.65) between basal seta of third valvula and apex (Fig. 15). Midlobe of mesosoma usually with 4 pairs of setae, preapical pair not reaching base of apical pair. Fore wing usually more than 2.7 times as long as broad (92.8% of specimens examined), if between 2.6 and 2.7 times, then clava less than 0.14 mm in dorsal length . . . . ***E. protransvena* Viggiani**



Figs. 5–12. *Encarsia bimaculata*: 5–11, female; 5, body; 6, mid tibia; 7, antenna; 8, mid tarsus; 9, mouthparts; 10, base of fore wing; 11, fore wing; 12, antenna of male. Arrow points to apical two costal cell setae diagnostic of the *strenua* group.

Encarsia bimaculata Heraty and Polaszek, new species
(Figs. 5–12)

Female.—Antenna with 6 flagellomeres, clava 3-segmented; F1 2.0–2.2× as long as broad and as long as F3; antenna yellow basally, slightly darkened apically. Head confused transverse colliculate (as in fingerprint), ocellar triangle similar but sculpture somewhat areolate; yellow except for a pale transverse band of brown across back of head; dorsal setae slight. Maxillary palpus 1-segmented. Mandibles 3/3 dentate, marginal teeth acute. Mesosoma mostly yellow except following which are brown: pronotum, midlobe of mesoscutum anteriorly and medially, tegula, axilla and propodeum submedially. Mesosoma with light hexagonally areolate sculpture dorsally; midlobe with 4 pairs of



Figs. 13–16. 13–14, *Encarsia citri*: 13, antenna of male; 14, third valvulae. 15, *Encarsia protransvena*, third valvulae; 16, *Encarsia strenua*, third valvulae.

setae, setae delicate and about equal in size, side lobe with 3 pairs, axilla with 2 pairs (lateral pair minute) and scutellum with 2 pairs. Scutellar sensillae ovoid and separated by less than their own maximum diameter; median groove usually narrow and distinct. Apical spur of mid tibia 0.6–0.8× as long as basitarsus; basitarsomeres of midtarsus without pegs. Tarsal formula 5-5-5. Fore wing 2.58–2.99× as long as broad, marginal fringe 0.25–0.36× width of fore wing; disc uniformily setose; costal cell with row of 9–10 minute setae and with 1 long marginal setae apically; submarginal vein with 2 large setae, basal area with 5–6 setae posterior to submarginal vein; frenal fold with several prominent thornlike spines; wing mostly hyaline, weakly infuscate at base of submarginal vein and base of frenal fold. Metasoma mostly yellow, tergites I + II mostly brown, sometimes with faint medial spot on tergites V + VI; laterally with weak cellulate reticulation; dorsal setal formula from tergite III: 2-2-2-6-6-6. Ovipositor 1.09–1.38× as long as mid tibia, 1.33–1.78× as long as clava, 0.6× as long as gaster (base to tip of third valvula); third valvula stout, 1.6–2.2× as long as broad, slightly extruded beyond epygium, entirely yellow.

Male.—Coloration similar to female but darker with entire metasoma brown, head with a transverse medial band of brown infuscation, and wings may be weakly infuscate in the basal half. Antenna with 6 flagellomeres, apical two flagellomeres fused, with segments distinctly separated (Fig. 12).

Comments.—This species is similar to *E. dialeurodis* Hayat for all features except for the darker coloration of the axillae, pronotum and mesoscutum (medially) (versus all yellow in *E. dialeurodis*) and F1 about equal in length to F2 (versus distinctly subequal). It is readily distinguished from other species of the *strenua* group by the dark mesosomal coloration of females and the shorter ovipositor to clava ratio. The only noticable difference in female coloration was a more extensive dark pigmentation of the metasoma in the specimens from Hong Kong, with gastral tergites V & VII almost completely dark; otherwise these did not differ from other specimens. Two smashed specimens from Thailand, one reared from *Bemisia tabaci* but with no other data, and the other from *Bemisia tabaci* on *Gossypium hirsutum* (Ban Ton Tea, 20.i.1992, F. Bennett 1224 [= *Encarsia* sp. in Nguyen & Bennett 1995]; both ♀ USNM), are identical for all characters of this species, except the ocellar triangle is transversely aciculate, the mandibles are less acutely toothed and the mid tibial spur is only 0.44× as long as the basitarsus. It is of interest that, assuming a random sampling, the original shipment of material of *E. bimaculata* from India (#1248) was only slightly biased for females (6:4), whereas, except for the Honduras lab culture (1:17), only two males have been discovered in all of the subsequent rearings. Another undescribed species in Florida (Gainesville; USNM) is very close, but it has a proportionally longer ovipositor (>2.0X as long as the clava), the female gaster is entirely dark, and the legs are also brown. This other species has also been reared from *Bemisia* and *Trialeurodes abutilonea*. *Encarsia bimaculata* is the *Encarsia* I [India], G [Guatemala] and S [Sudan] species released in Florida against *Bemisia argentifolia* (Nguyen & Bennet 1995).

Host.—Reared from *Bemisia argentifolia and B. tabaci* (Aleyrodidae).

Distribution.—India, Philippines, Thailand and USA (Florida, Texas?), and possibly Sudan, Israel and Mexico [possibly culture contaminations].

Material Examined.—Holotype, ♀, India: Tabarbhani, 19.vii.1994, culture in Gainesville, Florida, R. Nguyen, autoparasitoid, M92018. Deposited in USNM. Paratypes (80 females, 29 males): **Honduras**: lab culture [Florida] vi.1992, quarantine 1261 (1♀ 17♂ USNM). **Hong Kong**: Kowloon Park, 14.vii.1992, F. Bennett Y944, *Bemisia tabaci* on *Chamaescye? hirta* (2♀ USNM). **India**: same data as holotype (4 ♀, USNM, 7♀ 1♂ BMNH, 10♀ 1♂ UCRC); quarantine [Florida], 30.v.1991, R. Nguyen 903, 1065, 1248, *Bemisia tabaci* (6♀ USNM); Tabarhani, 14.iv.1992, R. Nguyen, ex *Bemisia tabaci* on *Hibiscus* (3♀ USNM); lab culture [Florida] quarantine, original shipment 1248, 1992 (6♀ 4♂ USNM). **Phillipines**: Benguet, 8.iii.1994, Legaspi, Carruthers, Poprawski, ex *Bemisia tabaci* on white potatoes, autoparasitoid, M94014 (11♀ UCRC, 5♀ BMNH); Quezon Dolores, 15.xii.1993, C. Moomaw, M93069, on eggplant (2 ♀ TAMU). **Israel**: [lab culture in Florida], R. Nguyen 1250, on *Bemisia tabaci* (7♀ 1♂ USNM). **USA**: Florida: Alachua Co., Gainesville, 7.ix.1992, F. Bennett Y935, *Bemisia tabaci* on *Euphorbia heterophylla* (2♀ 1♂ USNM); Alachua Co., Gainesville, 14.ix.1992, F. Bennett Y958, *Bemisia tabaci* on *Sesamum* (2♀ USNM); Alachua Co., Gainesville, 27.viii.1992, F. Bennett Y936, *Bemisia tabaci* on *Sesamum indicum* (2♀ 2♂ USNM); Alachua Co., Gainesville, 6.ix.1992, F. Bennett Y934, *Bemisia tabaci* on *Chamaesyce hirta* (3♀ 1♂ USNM); Hamilton Co., Jasper, 8.iv.1992, F. Bennett Y693, *Magnolia* sp. (1♂ USNM); Texas: Mission biological control laboratory (in culture from India), 16.xii.1993, M92018 (5 ♀ TAMU). **Mexico**: Taxco, 1992, P. Stansley 1292, *Bemisia tabaci* on *Chamaesyce hyssopifolia* (1♀ USNM). **Sudan**: [lab culture in Florida], 30.iv.1992, R. Nguyen 1249, on *Bemisia tabaci* (3♀ USNM). **Thailand**: xi.1977, G. Yonimoton [?], cotton (1♀ USNM).

Encarsia citri (Ishii)
(Figs. 13, 14)

Prospaltella citri Ishii, 1938: 29–30. Type data: Japan: Nagasaki. Syntypes, female. Type depository: National Institute of Agroenvironmental Sciences, Tsukuba, Japan. Described: female. Reared from *Dialeurodes citri*.

Encarsia strenua; Polaszek *et al.* 1992: 338. Incorrect synonymy.

Encarsia citri, Huang & Polaszek 1998: 352. Revised status.

Female.—Antenna with 6 flagellomeres, clava 3-segmented; F1 2.4–3.0× as long as broad and 0.9× as long as F3; antenna very pale brown, contrasting in color to rest of the body which is yellow. Vertex weakly areolate to colliculate, ocellar triangle weakly areolate; dorsal setae stout. Maxillary palpus 1-segmented. Mandibles chisel-shaped or very weakly 3/3 dentate, apical margin nearly flat. Mesosoma with weak hexagonally areolate sculpture dorsally; midlobe with 5 pairs of setae (rarely 6 pairs), posterior and lateral setae only slightly stouter than medial setae, side lobe with 3 pairs, axilla with 2 pairs (lateral pair minute), and scutellum 2 pairs, medial pair lateral to sensillae. Scutellar sensillae ovoid and separated by less than than their own maximum diameter (rarely by a full diameter); median groove distinct. Apical spur of mid tibia 0.7–0.8× as long as basitarsus; basitarsomere of midtarsus with 2–3 strong pegs, tarsomeres 3–5 each with 1 apical peg. Tarsal formula 5–5–5. Fore wing 2.39–2.68× as long as broad, marginal fringe 0.18–0.25× width of fore wing; disc uniformly setose; costal cell with row of 15–19 small setae and 2–3 long marginal setae apically; submarginal vein with 2 (rarely 3 on one side) large setae, basal area with 7–9 setae posterior to submarginal vein; frenal fold with several minute thornlike spines; wing hyaline. Metasoma yellow; laterally with weak cellulate reticulation; dorsal setal formula from tergite III: 2-2-2-6-6-6. Ovipositor 1.22–1.34× as long as mid tibia, 2.00–2.34× as long as clava, 0.5–0.6× as long as metasoma (base to tip of third valvula); third valvula stout (Fig. 14), 1.26–1.95× as long as broad, barely, if at all, extruded beyond epygium, entirely yellow.

Male.—Overall coloration pale brown, darker brown pattern on head and mesosoma similar to *E. bimaculata* female, gaster entirely brown. Setation pattern of mesosoma and metasoma as in female; some males with fewer setae in basal area (13) or fore wing and costal cell (4). Basitarsomere of middle leg with only 2 pegs. Antenna with 5 flagellomeres, apical two flagellomeres (5&6) fused, with segments distinguished only by a break in the pattern of linearia (Fig. 13).

Comments.—The shape and setation of the third valvula are distinct among all members of the *strenua* group. This species is most easily confused with *E. protransvena* but can be separated by the features outlined in the key and usually the presence of 5 pairs of setae on the midlobe of the mesoscutum (versus 4 pairs).

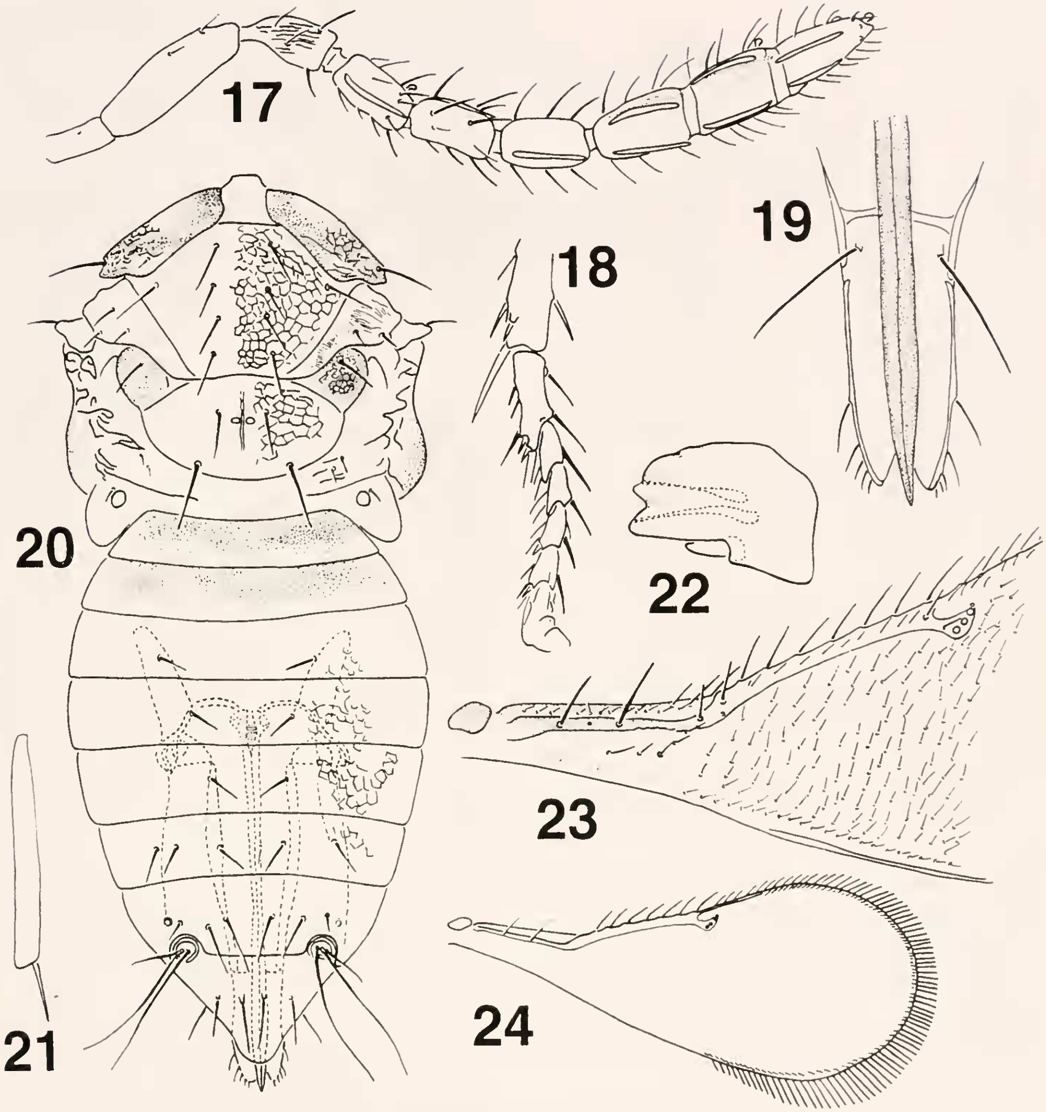
Hosts.—**Aleyrodidae**: *Dialeurodes citri* (Ashmead) (Ishii 1938).

Distribution.—**Palaearctic**: Japan (Ishii 1938).

Material Examined (6 males, 12 females).—**Japan**: Kyushu: Kagoshima City, 2.v, 15.vii.1970, S. Ohga, R70-31, R72-36, *Dialeurodes citri* on *Citrus* spp. (12♀ 4♂ 1 pupa UCRC); Kagoshima, Taremian, 18–19.viii.1972, S. Ohga, R72-50 (2♂ UCRC [with 2♂ of *E. transvena* on same slide]); Fukuoka, Tsuyazaki, 4.viii.1995, H. Kajita, ex *Dialeurodes citri* on *Citrus* (2♀ BMNH).

Encarsia neocala Heraty and Polaszek, new species
(Figs. 17–24)

Female.—Antenna with 6 flagellomeres, clava 3-segmented; F1 1.6–1.9× as long as broad and 0.8–1.0× as long as F3; antenna yellow basally, darkened beyond or including pedicel. Vertex confused transverse colliculate, ocellar triangle similar but sculpture somewhat areolate; head yellow except for weak infuscation on inner margins of ocelli; dorsal setae slight. Maxillary palpus 1-segmented. Mandibles 2/2 or 3/3 dentate, ventral teeth acute, dorsal tooth blunt or rounded and often not apparent. Mesosoma mostly yellow except pronotum brown and axillae and propodeum laterally pale brown. Mesosoma with light hexagonally areolate sculpture dorsally; midlobe with 4–5 pairs of setae, posterior and lateral setae only slightly stouter than medial setae, side lobe with 3 pairs, axilla with 2 pairs (lateral pair minute), and scutellum 2 pairs, medial pair lateral to sensillae. Scutellar sensillae ovoid and separated by less than than their own maximum diameter; median groove narrow and distinct. Apical spur of mid tibia 0.8–1.0× as long as basitarsus; basitarsomere of midtarsus with 2–4 strong pegs, tarsomeres 4 and 5 each with 1 apical peg. Tarsal formula 5–5–5.



Figs. 17–24. *Encarsia neocala*, female: 17, antenna; 18, midtarsi; 19, third valvulae; 20, body; 21, mid tibia; 22, mandible; 23, base of fore wing; 24, fore wing.

Fore wing 2.32–2.44× as long as broad, marginal fringe 0.29–0.38× width of fore wing; disc uniformly setose; costal cell with row of 12–16 small setae and 2–4 long marginal setae apically; submarginal vein with 2 large setae, basal area with 4–5 setae posterior to submarginal vein; frenal fold with several minute thornlike spines; wing mostly hyaline, weakly infuscate at base of submarginal vein. Metasoma mostly yellow, tergites I + II usually brown, sometimes almost completely yellow; laterally with weak cellulate reticulation; dorsal setal formula from tergite III: 2-2-2-6-6-6. Ovipositor 1.60–1.79× as long as mid tibia, 2.16–2.56× as long as clava, 0.7× as long as metasoma (base to tip of third valvula); third valvula elongate (Fig. 19), 2.6–3.0× as long as broad, extruded beyond epygium, entirely yellow.

Male.—Unknown.

Comments.—The longer third valvulae, longer ovipositor relative to gaster length, and stouter ovipositor (indicated by a tendency for the tip to be bent in slide mounts) place this species as similar to *E. strenua*. However, in *E. neocala* the third valvula is entirely yellow (versus tipped brown in *E. strenua*), the midlobe of the mesoscutum is entirely yellow with the axillae slightly darker (versus entirely yellow or the midlobe slightly darkened anteriorly in *E. strenua*), fewer setae in the costal cell, and the ocellar triangle more weakly sculptured.

Host.—Reared from *Orchamoplatus caledonicus* (Dumbleton) (Aleyrodidae) [reads Orchamnus neocaledonicus on label] on *Citrus*.

Material Examined.—Holotype, ♀, New Caledonia, Nouméa, 10.ix.1970, G. Fadres, ex [Orchamnus neocaledonicus]. Deposited in USNM. Paratypes (37 females): same data, (5♀ USNM, 5♀ BMNH, 27♀ UCRC).

Encarsia protransvena Viggiani
(Figs. 15, 25–28)

Encarsia protransvena Viggiani, 1985a: 89–90. Type data: USA: FL, Broward Co., Fort Lauderdale. Holotype female, by original designation. Type depository: IEUN. Described: female. Illust. Reared from *Dialeurodes kirkaldii*. Placed in *strenua* group by Hayat (1989).

Encarsia strenua; Polaszek *et al.* 1992: 388. Described: female. Illust. (in part).

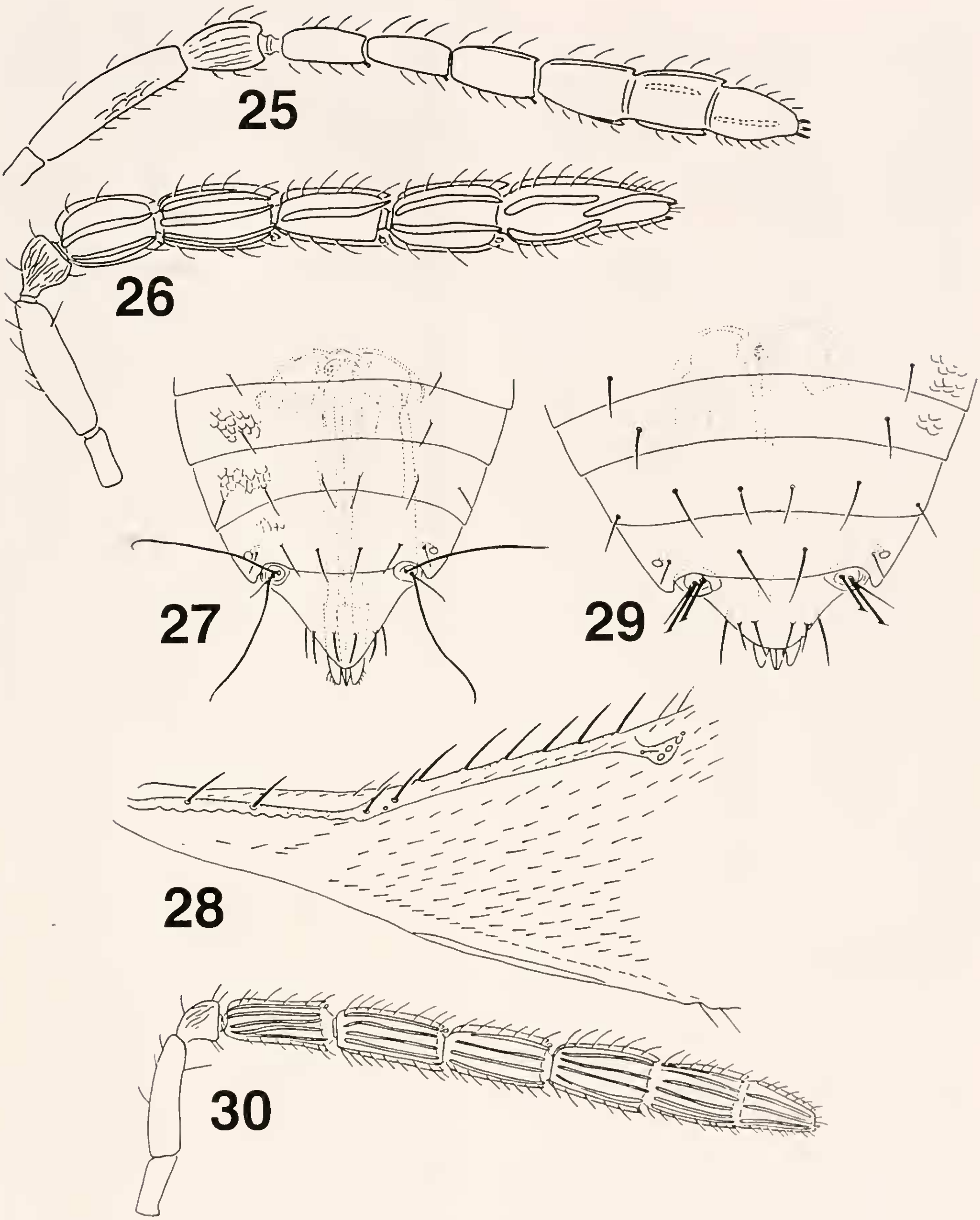
Encarsia strenua; Schauff *et al.* 1996: 29. Described: female. Illust. Misidentification.

Encarsia protransvena; Schauff *et al.* 1996: 27. Described: female. Illust.; Huang & Polaszek 1998: 1941; Polaszek *et al.* 1999: 158.

Female.—Antenna with 6 flagellomeres, clava 3-segmented; F1 2.1–3.2× as long as broad and 0.7–1.1× as long as F3; antenna and entire body yellow except small spots of brown along inner margins of ocelli. Vertex weakly areolate, ocellar triangle areolate; dorsal setae stout. Maxillary palpus 1-segmented. Mandibles 3/3 dentate, teeth sharp or blunt. Mesosoma with weak hexagonally areolate sculpture dorsally; midlobe usually with 4 pairs of setae (rarely with as few as 3 setae per side and as many as 5 pairs total), posterior and lateral setae much stouter than medial setae (almost twice as broad), side lobe with 3 pairs, axilla with 2 pairs (lateral pair minute), and scutellum 2 pairs, medial pair lateral to sensillae. Scutellar sensillae ovoid and separated by less than than their own maximum diameter (rarely by a full diameter); median groove distinct. Apical spur of mid tibia 0.8–0.9× as long as basitarsus; basitarsomere of midtarsus with 2–3 strong pegs, tarsomeres 3–5 each with 1 apical peg. Tarsal formula 5-5-5. Fore wing 2.62–3.11× as long as broad, marginal fringe 0.20–0.40× width of fore wing; disc uniformly setose; costal cell with row of 12–18 small setae and 1–3 long marginal setae apically; submarginal vein with 2 large setae, basal area with 7–9 setae posterior to submarginal vein; frenal fold with several minute thornlike spines; wing hyaline. Metasoma laterally with weak cellulate reticulation; dorsal setal formula from tergite III: 2-2-2-6-6-6. Ovipositor 1.29–1.74× as long as mid tibia, 2.0–3.37× as long as clava, 0.6–0.7× as long as metasoma (base to tip of third valvula); third valvula stout (Fig. 15), 1.7–2.8× as long as broad, barely, if at all, extruded beyond epygium, entirely yellow.

Male.—Overall coloration pale brown, darker brown pattern on head and mesosoma similar to *E. bimaculata* female, gaster entirely brown. Setation pattern of mesosoma and metasoma as in female, but difference in size of setae on midlobe of mesoscutum much less. Costal cell with 9–10 small setae and basal area with 5–7 setae. Basitarsomere of middle leg with only 2 pegs. Antenna with 5 flagellomeres, apical two flagellomeres (5&6) fused with linearia overlapping (Fig. 26).

Comments.—This species can be separated from other members of the *strenua* group by the shorter ovipositor and third valvulae, more delicate antenna (clava



Figs. 25–30. 25–28, *Encarsia protransvena*: 25, antenna of female; 26, antenna of male; 27, apex of gaster, dorsal view; 28, base of fore wing. 29, *Encarsia sophia*, apex of gaster. 30, *Encarsia strenua*, antenna of male.

only slightly broader than the funicle), and longer fore wing. The setae of the midlobe of the mesosoma are usually arranged in 4 pairs (rarely 3 or 5), whereas they are almost always arranged in 5 pairs in *E. citri*, and the arrangement of setae (shorter and more apical) on the third valvulae is distinct from *E. citri*. Of the hundreds of specimens examined, only the two males, collected at the same locality as other *E. protransvena* females, can be attributed to this species. This is probably the parasite recorded as *Encarsia strenua* attacking *Bemisia argentifolia* in South Carolina (Simmons 1998).

The specimens of *E. protransvena* described from China (1 female) and Taiwan (2 females) by Huang & Polaszek (1998) are nearly identical to those described in this paper. However, the taiwanese specimens have a band of 14 setae in the basal area of the fore wing (their fig. 273) as compared to a single row of only 7–9 setae in both *E. protransvena* and *E. citri*. They also describe 5 pairs of setae on the midlobe of the mesosoma, which is rarely encountered in specimens from the New World (usually 4 pairs). The chinese specimen agrees for all characters with *E. protransvena*, but it has a strongly and densely reticulate vertex, as compared to the very weak and more broadly spaced sculpture of all other *E. protransena* examined, and the basal segment of the clava is more distinctly separated from the following segment. More material will need to be examined before these can be included or excluded from *E. protransvena* with confidence.

Hosts.—**Aleyrodidae**: *Aleurotrachelus rubi* Takahashi (Huang & Polaszek 1998), *Bemisia argentifolia* Bellows & Perring, *Bemisia tabaci* (Gennadius), *Dialeurodes citri* (Ashmead), *Dialeurodes citrifolii* (Morgan), *Dialeurodes kirkaldii* (Kotinsky) (Viggiani 1985a), *Parabemisia myricae* (Kuwana), *Trialeurodes abutiloneus* (Haldeman), *Trialeurodes packardi* (Morrill) (Huang & Polaszek 1998), *Trialeurodes variabilis* (Quaintance). **Diaspididae**: *Aspidiotus* sp.?, *Parlatoria ziziphi*?. [diaspidid hosts almost certainly are incorrect associations]

Distribution.—**Nearctic**: United States of America: California (Polaszek *et al*. 1992), Florida (Viggiani 985a), Hawaii (Nguyen & Hamon 1989 [not examined]). **Neotropical**: Colombia; Cayman Islands; Honduras (Polaszek *et al*. 1992); Puerto Rico (Polaszek *et al*. 1992). **Palaearctic**: Spain; Egypt (Polaszek *et al*. 1999). **Oriental**: People's Republic of China: Guangdong; Taiwan (Huang & Polaszek 1998).

Material Examined (390 females, 2 males). **Colombia:** Valle: Dagua, 28.v.1991, R. Caballero, 108, *Dialeurodes citrifolii* on *Citrus aurantifolia* (4♀ USNM). **Grand Cayman:** Cayman, 13.vi.1986, F.D. Bennett, Y729, whitefly on *Citrus* (1♀ USNM); Savannah, 17.x.1987, F.D. Bennett, 164, *Dialeurodes citrifolii* on *Citrus* (2♀ USNM). **Puerto Rico:** Rio Piedras, 5.v.1990, 4.vi.1990, 18.ix.1988, 18.xi.1988, 24.xi.1988,, F.D. Bennett, Y501, Y560, Y1042, Y1043, Y1051, 128, 828, 1585, *Dialeurodes citrifolii* on *Citrus*, *Dialeurodes citri* on *Citrus*, *Dialeurodes kirkaldyi* on *Jasminum*, *Gymnaspis* on bromeliad (15♀ USNM); Corozal, 27.xi.1988, 1.xii.1989, F.D. Bennett, 159, 161, *Dialeurodes citrifolii* on *Citrus* (5♀ USNM); Adjuntas, 15.xi.1988, F.D. Bennett, Y719, Y1045, Y1046, 163, *Dialeurodes citrifolii* on *Citrus* (8♀ USNM); Mayaquez, 16.xi.1988, F.D. Bennett, Y1047, 160, *Dialeurodes citrifolii* on *Citrus*, *Parlatoria ziziphi* on *Citrus* (5♀ USNM); Fortuna, 3.xii.1987, F.D. Bennett, 151, *Dialeurodes* on *Citrus* (8♀ USNM). **Spain:** Valencia, xi.1994, F.S. Mari, *Parabemisia myricae* (4♀ USNM). **USA: Florida**: Dade County: North Miami "Little Haiti", 28.v.1987, 22.vi.1987, R. Prange & F.D. Bennett, RP-1, *Dialeurodes citrifolii* on *Citrus* (20♀ 1♂ TAMU); 17.x.1987, F.D. Bennett & H. Glenn, FDB-3, *Dialeurodes citrifolii* on *Citrus*, *Dialeurodes citrifolii* on *Dioscorea alata* (10♀ TAMU); 19.i.1986, F.D. Bennett, J.H. Frank & R. Nguyen, *Dialeurodes citrifolii* on *Citrus* (1♀ USNM); 12.x.1987, F.D. Bennett, 1331, *Aspidiotus destructor* on *Dioscorea alata*, *Dialeurodes citrifolii* on *Dioscorea alata* (3♀ USNM); Miami, 12.x.1987, F.D. Bennett & H. Glenn, 87, *Dialeurodes citrifolii* on *Dioscorea alata* (6♀ 1♂ USNM); 29.x.1990, F.D. Bennett, 746, *Bemisia tabaci* on *Ricinus communis* (1♀ USNM). Alachua County: Gainesville, records for every month of the year, 1989 to 1993, collectors include F.D. Bennett, G.A. Evans, J. Marenco and L. Nong, host records include *Bemisia tabaci* on soybean, *Bemisia tabaci* on *Emilia sonchifolia*, *Trialeurodes abutilonea* on *Hibiscus mutabilis*, *Trialeurodes packardi* on *Cercis canadensis*, *Dialeurodes citri* on *Ligustrum sinense*, *Dialeurodes citri* on *Viburnum*, *Dialeurodes citrifolii* on *Citrus*, *Bemisia tabaci* on *Sesamum indicum*, *Bemisia tabaci* on *Chamaesyce hyssopifolia*, *Bemisia tabaci* on *Cassia obtusifolia*, *Bemisia tabaci* on *Euphorbia heterophylla*, *Bemisia tabaci* on *Brassica oleracea* var. *acephala*, *Bemisia tabaci* on *Hibiscus mutabilis*, *Bemisia tabaci* on *Desmodium tortuosum* (170♀ USNM); Micanopy, 3.iv.1988, 28.vii.1991, 11.ix.1988, 21.ix.1989, 21.x.1989, F.D. Bennett, Y287, 1, 95, 127, 154, 771, *Dialeurodes citri* on *Citrus*, *Dialeurodes citri* on *Viburnum*, *Dialeurodes citri* on *Melia azadarach*, *Trialeurodes packardi* on *Cercis canadensis* (18♀ USNM); Alachua, xi.1992, H. McAuslane, 1339, *Bemisia tabaci* on peanut (3♀ USNM); near Alachua, 12.ix.1991, F.D. Bennett, Y399, Y400, *Bemisia tabaci* on soybean 5♀ (USNM). Monroe County: Isla Morada, 1.v.1993, F.D. Bennett, Y1060, *Dialeurodes citrifolii* on *Citrus aurantifolia* (3♀ USNM). Broward County: Pompano Beach, 22.iii.1992, 23.vii.1991, 23.viii.1991, 4.xi.1988, F.D. Bennett, Y274, Y437, Y490, Y664, *Bemisia tabaci* on *Emilia sonchifolia, Dialeurodes citrifolii* on *Citrus, Dialeurodes kirkaldyi* on *Jasminum* (10♀ USNM). Orange County: Apopka, 29.xi.1989, K. Hoelmer, 380, *Trialeurodes variabilis* on *Carica papaya* (2♀ USNM). Indian River County: Beach, 10.iv.1987, D. Mooney, *Crenidorsum* new species on *Coccoloba uvifera* (2♀ USNM). Jackson County: Mariana, 18.viii.1987, F.D. Bennett, 946, *Dialeurodes citri* on *Melia* (25♀ USNM). Bradford County: Starke, 26.iv.1989, W.A.A. Klerks, *Pseudaulacaspis cockerelli* (1♀ USNM). Gadsden County: Quincy IFAS, 13.ix.1991, F.D. Bennett, Y396, Y401, *Bemisia tabaci* on soybean, *Bemisia tabaci* on tomato (4♀ USNM). Palm Beach County: West Palm Beach, 6.ii.1991, 1.iv.1991, 13.vi.1992, 19.x.1991, F.D. Bennett, F104, Y428, Y450, Y838, 1183, *Dialeurodes kirkaldyi* on *Jasminum, Bemisia tabaci* on *Chamaesyce hyssopifolia, Bemisia tabaci* on *Emilia sonchifolia* (8♀ USNM). Hillsborough County: Ruskin, 29.vi.1990, *Eclipta* (1♀ USNM). Osceola County: Orange Creek, 18.iii.1990, F.D. Bennett, 407, *Trialeurodes abutilonea* on *Solanum americanum* (1♀ USNM); Canoe Creek, 22.xi.1990, F.D. Bennett, 1091, *Dialeurodes* or *Aleurothrixus floccosus* on *Citrus* (1♀ USNM). County?: Brywood, 4.vi.1992, F.D. Bennett, Y901, black whitefly on *Liquidambar styraciflua* (1♀ USNM). **South Carolina:** Charleston County: Charleston, 31.viii.1993, 7.ix.1993, 29.ix.1993, A. Simmons, 1610, 1614, 1615, *Bemisia tabaci* on sweetpotato (2♀ USNM). **Mississippi:** Simpson County: Magee, 10.ix.1994, D.H. Headrick, DHH96-0423, DHH96-0424, DHH96-0438, *Bemisia argentifolii* on *Cleome hasslerana* (3♀ UCRC). Forrest County: Hattiesburg, 5.ix.1994, D.H. Headrick, DHH94-0361, *Bemisia argentifolii* on okra (1♀ UCRC). **Georgia:** Bryan County: Savannah, 15.xi.1991, F.D. Bennett, 1161, *Bemisia tabaci* on *Chamaesyce hyssopifolia* (6♀ USNM). Tift County: Tifton, 20.x.1992, J. Chamberlain, 1355, 1395, *Bemisia tabaci* on *Gossypium hirsutum* (11♀ USNM); 29.iv.1992, 15.ix.1992, W. Hudson, Y714, Y715, Y716, Y717, 1346, *Bemisia tabaci* on *Gossypium hirsutum, Dialeurodes citri* on *Jasminum* (21♀ USNM).

Encarsia sophia (Girault & Dodd)
(Fig. 28)

Coccophagus sophia Girault & Dodd, 1915: 49, 56. Type data: Australia: QLD, Cairns. Syntypes, female. Type depository: Brisbane: Queensland Museum, Queensland, Australia; type no. Hy.2926.

Prospaltella transvena Timberlake, 1926: 312–315. Type data: USA: Hawaii, Oahu. Holotype female. Type depository: Honolulu: Bernice P. Bishop Museum, Dept. Ent. Coll., HI, USA; type no. 5690. Described: both sexes. Illust. Reared from *Trialeurodes* [as *Aleyrodes*] *vaporariorum* on tomato. Placed in *lahorensis* group by Hayat (1989) and in *strenua* group by Polaszek *et al.* (1992) and Hayat (1998). Gerling (1985) states that *E. sublutea* is known in Hawaii as *E. transvena*. **New Synonymy.**

Prospaltella sophia; Compere 1931: 11. Change of combination.

Prospaltella sublutea Silvestri, 1931: 20–22. Type data: Somalia: Duca [?]. Syntypes, female. Type depository: IEUN. Described: female. Illust. Synonymy with *transvena* by Gerling & Rivnay in Viggiani 1985: 90.

Prospaltella bemisiae Ishii, 1938: 30. Type data: Japan: Ikawa-cho, Mei-Ken. Syntypes, female. Type depository: National Institute of Agroenvironmental Sciences,Tsukuba, Japan. Described: female. Synonymy with *transvena* by Polaszek *et al.* 1992: 388–389. Reared from *Parabemisia* [as *Bemisia*] *myricae* Kuwana.

Prospaltella flava Shafee, 1973: 254–255. Type data: India: Uttar Pradesh, Aligarh. Holotype female, by original designation. Type depository: Aligarh: Aligarh Muslim University, Deptartment of Zoology, India. Described: female. Illust. Synonymy by Hayat 1989: 72. Preoccupied by *flavus* Compere 1936: 300. Questionably treated as a junior synonym of *transvena* by Viggiani (1985). The type material was reared from a coccid which, if correct, represents a significant departure in host range.

Encarsia sophia; Viggiani 1985b: 249. Described: female. Illust. Change of combination.

Encarsia transvena; Gerling & Rivnay in Viggiani 1985a: 90–92. Described: both sexes. Illust. Change of combination.

Encarsia shafeei Hayat, 1986: 163. Replacement name for *E. flava* Shafee.

Encarsia transvena; Hayat 1989: 71–73; Polaszek *et al.* 1992: 388–389; Schauff *et al.* 1996: 31–33; Hayat 1998: 205–207; Huang & Polaszek 1998: 1954–1956. Described: both sexes. Illust.

Comments.—This is the most distinctive species in the *strenua* group and can be recognized by the transversely striate ocellar triangle, a patch of longer setae in the posterior half of the wing disc, and presence of only 4 setae on Mt7 (Polaszek *et al.* 1992; Schauff *et al.* 1997). All of the female specimens examined were completely yellow except for a single female from Thailand (ex *Bemisia tabaci* on *Lantana camarara* [USNM]), which has the same dark pattern of colour as *E. bimaculata*.

The type specimen of *E. sophia*, like most of the Girault material, is in poor condition; however, all of the diagnostic features shared with *E. transvena*, and other species names currently synonymized with *E. tranvena*, are clearly visible. Since it was described as different species in Australia (Girault & Dodd 1915), Hawaii (Timberlake 1926), Somalia (Silvestri 1931), and Japan (1938), we assume that this group was widespread in the Old World, prior to recent movements of species for use in the biological control of whiteflies. Both authors of this paper have examined several hundred *E. transvena* from around the world and found no diagnostic characters that would separate any population as distinct from the others. Recent studies, however, have shown mating incompatibilities and morphometric (shape) differences between populations of *E. transvena* from Spain and Pakistan (G. Viggiani, pers. comm.) that allude to the potential for this to be a cryptic or sibling species complex. Should we proceed with the synonymy or wait for further evidence of potential species boundary characteristics? The synonymy is justified on both philosophical and practical grounds. For practical purposes, the assignment of an appropriate specific epithet to any of the geographically isolated populations is complicated by their taxonomic history. Five names were proposed within this complex, of which *E. sophia* is the oldest, and *E. transvena* (described from Hawaii, where it may have been accidentally introduced from Japan, southeast Asia or Australia) is probably the least applicable to the populations from Pakistan or Spain under study. If there has been some accidental movement, especially to Hawaii (type locality of *E. transvena*), determining the origin and movements through introductions of each geographical population will be essential to the correct assignment of names, if this is indeed a species complex.

Especially for the purposes of biological control and the associated need for accurate identification of museum and field material, what concept of a species is most useful? Among the many definitions proposed, there are only two basic and, in some ways opposable, concepts. The Biological Species Concept (Mayr 1963) requires that populations of the same species, whether they are in contact or not, have the potential to interbreed. The degree and conditions under which interbreeding will take place are problematic (Donoghue 1985), especially when they are used to assess allopatric populations that have varying degrees of reproductive incompatibility (cf. Rosen & DeBach 1979). The ability to interbreed in Aphelinidae and other Chalcidoidea can be further complicated by other factors, such as endosymbiotic bacteria that can induce reproductive incompatibility within or between populations (O'Neill *et al.* 1997; Luck *et al.* in press). These incompatible populations can even be cured through antibiotics or heat treatments and interbreeding reestablished (Stouthamer & Luck 1993; Luck *et al.* in press), which brings into question the criterion of incompatibility for separating otherwise indistinguishable populations that have been treated previously as either cryptic, sibling or semi species. In contrast, under a Phylogenetic Species Concept (Donoghue 1985), at least one diagnostic character is required for each species to denote an evolutionary lineage. The simple notion of reproductive incompatibility, the foundation of the Biological Species Concept, is not sufficient. A discrete morphological character found in all individuals is usually taken as the best criterion for separating species; species are both diagnosable and unique. Whether both molecular and morphometric (shape) characteristics are considered diagnostic under a Phylogenetic Species Concept is debatable, especially since they may be describing only population level differences that do not contribute to the "potential" for a species to interbreed (Avise & Wollenberg 1997). In any case, differences must be demonstrated over the range of a species to assure that they are not merely representative of clinal variation in a series of populations belonging to a single species. Currently, *E. sophia* and *E. transvena*, and all of the names synonymized of *E. transvena*, cannot be distinguished using diagnostic morphological characters, and synonymy under the oldest valid senior name, *E. sophia*, is justified.

Hosts.—**Aleyrodidae:** *Acaudaleyrodes rhachipora* (Singh) (Hayat 1989), *Aleurocybotus indicus* David & Subramaniam (Polaszek *et al.* 1992), *Aleurodicus dispersus* Russell (Polaszek *et al.* 1992), *Aleurolobus* sp. near *niloticus* (Hayat 1989a), *Bemisia*? (= *Aleyrodes*) *hibisci* (USNM 29067), *Bemisia tabaci* (Gennadius) (Polaszek *et al.* 1992, Hayat 1989, Gerling 1985), *Parabemisia myricae* (Kuwana) (Polaszek *et al.* 1992), *Pealius hibisci* (Kotinsky) (Timberlake 1926), *Trialeurodes ricini* (Misra) (Hayat 1998), *Trialeurodes vaporariorum* Westwood (Polaszek *et al.* 1992, Timberlake 1926, Gerling 1985). **Aphididae**: *Aphis sacchari* Zehntner? (Timberlake 1926). **Coccidae**:? (Shafee 1973). **Psyllidae**: *Diaphorina citri* Kuwayama (Polaszek *et al.* 1992). [The psyllid host is correct, although possibly *E. sophia* is a hyperparasitoid on *Tamarixia radiata* (Waterston) [Huang & Polaszek 1998], so the aphid and coccid associations also may be "primary" hosts of hyperparasitic males.]

Distribution.—Cosmopolitan in the Old World, introduced in the New World. **Afrotropical**: Burundi; Cape Verde (Hayat 1998); Ivory Coast; Morocco; Niger (Hayat 1998); Sierra Leone; Somalia (Silvestri 1931). **Oriental**: Hawaiian Islands (Timberlake 1926); Hong Kong; India (Hayat 1989); Indonesia; Sri Lanka (Hayat 1998); Pakistan (Hayat 1989); People's Republic of China (Huang & Polaszek 1998); Taiwan; Thailand. **Palaearctic**: Japan (Ishii 1938); Spain.

Material Examined (289 females, 71 males).—**Burundi:** Bujumbura, vii.1987, J. Yaninek, whitefly on Cassava (1♀ USNM). **Hong Kong:** Kowloon Park, 14.vii.1992, F.D. Bennett, Y944, *Bemisia tabaci* on *Chamaesyce* (?) *hirta* (1♀ USNM). **India:** Rajkot, 9.ii.1958, G.W. Angolet, whitefly on *Ricinus communis* (4♀ USNM); India (no other locality), 19.xii.1990, G. Butler, *Bemisia tabaci* (1♀ USNM). **Indonesia:** Java: Bandoeng, x.1929, C. P. Clausen, 2420, *Asterochiton* (10♀ UCRC). **Ivory Coast:** 20 km west of Abidjan, 21.iv.1988, L.D.C. Fishppol, 125, *Bemisia tabaci* on *Manihot esculentum* (2♀ USNM). **Japan:** Shikoku: Kochi, 23.vii.1980, P. DeBach, R.80.28, R.80.29, R.80.34, *Parabemisia myricae* on *Morus*, *Parabemisia myricae* on *Citrus* (43♀ 1♂ UCRC); 20–25.ix.1979, M. Rose, R79-67-1 & 2, *Parabemisia myricae* on *Morus* (13♀ 5♂ UCRC); Kyushu: Kagoshima City, 8.viii.1972, S. Ogo, R72-42, *Dialeurodes citri* on *Citrus* (3♀ UCRC); Honshu: Mie Prefecture, near Kuana City, 11, 15, 16, 18, 20, 21.viii.1981, M. Rose, R81-34, R81-35, R81-36, R81-37, R81-39, R81-40, R81-41, R81-42, *Parabemisia myricae* on *Morus* (60♀ 4♂ UCRC); Shizuoka, 17.vii.1981, 5.viii.1982, K. Furuhashi, R82-30, on *Morus* (4♀ UCRC); 22–24.viii.1981, M. Rose, R81-43, *Parabemisia myricae* on *Morus* (1♀ UCRC). **Morocco:** Agadir, vi.1992, *Parabemisia myricae* (1♀ USNM). **Niger:** 4.xi.1987, Hansen, CIE A19340, *Aleurocybotus indicus* on rice (1♀ USNM). **Pakistan:** Sialkot, 25.ix.1969, R. Ahmad, R69-110, *Dialeurodes citri* on *Citrus* (1♂ UCRC); Pakistan (no other locality), 15.v.1987, L. Osborne, 803, *Bemisia tabaci* (1♀ USNM). **People's Republic of China:** Sichuan Province: Bei-Pei District, 19.viii.1980, P. DeBach, C3, whitefly on *Morus* (7♀ 1♂ UCRC); Guangdong Province, Guangzhou, 11.vii.1992, F.D. Bennett, Y894, whitefly on *Lactuca* (1♂ USNM). **Sierra Leone:** viii.1960, *Bemisia* (7♀ USNM). **Spain:** Murcia, 19.vii.1994, EBCL—A. Kirk & L. Lacey, M93002, *Bemisia tabaci* on *Lantana* (19♀ UCRC). **Taiwan:** Tao-yuan, 3.xii.1993, C. Moomaw, Mission Biological Control Lab culture (Texas) M93054, *Bemisia* on *Poinsettia* (3♀ TAMU). **Thailand:** Chiang Mai, 14.iii.1994, L. Lacey & A. Kirk, M94041, *Bemisia tabaci* on Poinsettia (9♀ UCRC, 1♀ 1♂ TAMU); Chiang Mai University, 15.i.1993, F.D. Bennett, Y1009, whitefly on *Hibiscus mutabilis* (1♀ USNM); Pang Hang, 15.iii.1994, L. Lacey & A. Kirk, M94049, *Bemisia tabaci* on *Xanthium*; Ban Ton Tea, 20.i.1992, F.D. Bennett, 1224, *Bemisia tabaci* on *Gossypium hirsutum* (6♀ USNM); near Bangkok, iii.1992, F.D. Bennett, 1245, *Bemisia tabaci* on *Solanum melon-*

gena (6♀ USNM). **USA: Arizona:** Cochise County: Guadalupe Canyon, 31 miles east of Douglas, 14.ix.1978, J.B. Woolley, 78035, whiteflies on mesquite (1♀ TAMU). **Florida**: Dade County: Miami, 14.vi.1992, 21.vii. 1991, 22.vii.1991, 31.viii.1991, 19.x.1991, F.D. Bennett, Y276, Y277, Y358, Y459, Y834, *Bemisia tabaci* on *Chamaesyce hyssopifolia, Bemisia tabaci* on *Euphorbia*(11♀ 19♂ USNM); Homestead, 4.v.1992, F.D. Bennett, Y757, *Bemisia tabaci* on *Emilia sonchifolia* (1♂ USNM); Snapper Creek, 13.vi.1992, 14.vi.1992, 19.x.1991, F.D. Bennett, Y457, Y830, Y837, *Bemisia tabaci* on *Emilia sonchifolia, Bemisia tabaci* on *Chamaesyce hyssopifolia* (4♀ 4♂ USNM). Alachua County: Alachua, xi.1992, H. McAuslane, 1376, *Bemisia* on peanut (3♀ USNM); Gainesville, 19.iii.1968, M. Kosztarab 874, *Diaspis* on *Opuntia* (2♀ USNM); 3.v.1992, G.A. Evans, 1251, on *Ilex* (1♂ USNM); 27.viii.1992, F.D. Bennett, Y936, *Bemisia tabaci* on *Sesamum indicum* (1♀ USNM); Micanopy, 20.i.1990, F.D. Bennett, Y487, whitefly on *Citrus* (1♀ USNM). Saint Lucie County: Fort Pierce, 9.viii.1992, F.D. Bennett, Y904, *Bemisia tabaci* on *Emilia sonchifolia* (2♀ 1♂ USNM). Okeechobee: Fort Drum, 17.x.1991, F.D. Bennett, Y440, *Bemisia tabaci* on *Emilia* (3♀ 6♂ USNM). Orange County: Apopka, 15.viii.1988, L. Osborne, *Bemisia tabaci* on *Euphorbia* (17♀ 4♂ TAMU); 10.ix.1987, Rose & Osborne, T87032, *Bemisia tabaci* (?) on *Euphorbia* (4♂ TAMU); vi-vii.1989, 14.x.1989, 25.x.1989, 29.xi.1989, K. Hoelmer, *Bemisia tabaci* on *Lantana, Trialeurodes variabilis* on papaya (1♀ 3♂ USNM). Broward County: Pompano Beach, 22.iii.1992, v.1993, 10.viii.1992, 19.x.1991, 19.xi.1991, F.D. Bennett, Y448, Y541, Y665, Y908, Y1056, *Bemisia tabaci* on *Chamaesyce hyssopifolia, Bemisia tabaci* on *Emilia sonchifolia* (13♀ 7♂ USNM). Palm Beach County: West Palm Beach, 11.iv.1992, 10.viii.1992, 11.ix.1992, F.D. Bennett, Y907, Y933, 1559, *Bemisia tabaci* on *Emilia sonchifolia, Bemisia tabaci* on *Chamaesyce hyssopifolia* (3♀ 4♂ USNM). Monroe County: Isla Morada, 30.iv.1993, 18.x.1991, F.D. Bennett, Y453, Y1108, *Bemisia tabaci* on *Chamaesyce hyssopifolia, Bemisia tabaci* on *Chamaesyce hirto* (2♀ 1♂ USNM); Key Largo, 18.x.1991, F.D. Bennett, Y444, *Bemisia tabaci* on *Desmodium tortuosum* (3♀ 3♂ USNM). Manatee County: Bradenton, 13.v.1993, E. Vasquez, Y1053, *Bemisia tabaci* (4♀ 2♂ USNM). **Texas:** Hidalgo County, Mission Biological Control Lab, 16.xii.1993, M93002 (MBCL culture voucher specimen), *Bemisia tabaci* (1♀ TAMU). **California:** Orange County: U.C. South Coast Field Station, 15–16.xii.1982, S. Key, *Parabemisia myricae* on lemon (9♀ 1♂ UCRC); Los Angeles County: San Gabriel, 22.iv.1982, Rose & Ferrentino, *Parabemisia myricae* on orange (1♀ UCRC). **Hawaii:** Oahu: Moiliili, 15.iii.1984, B. Kumashiro, *Bemisia tabaci* on eggplant (7♀ TAMU).

Encarsia strenua (Silvestri)
(Figs. 16, 30)

Prospaltella strenua Silvestri, 1928: 34–36. Type data: China: Macao. Holotype female, by monotypy. Type depository: IEUN. Described: female. Illust. Reared from *Bemisia giffardii* on *Citrus*. Placed in *strenua* group by Viggiani & Mazzone (1979) and Hayat (1989).

Encarsia strenua, Viggiani & Mazzone, 1979: 46. Change of combination.

Encarsia strenua; Polaszek *et al.* 1992: 388; Schauff *et al.* 1996: 29. Described: female. Illust. Broadly defined to include what is now recognized as *E. protransvena* and *E. citri*.

Encarsia strenua; Polaszek & Huang 1998: 1951–53. Described: female. Illust. Based on Chinese and Taiwan material.

Female.—Antenna with 6 flagellomeres, clava 3-segmented; F1 2.6–3.6× as long as broad and 0.9–1.0× as long as F3; antenna yellow basally, darkened beyond or including pedicel. Vertex and ocellar triangle strongly areolate; head yellow except for weak infuscation on inner margins of ocelli; dorsal setae robust. Maxillary palpus 1-segmented. Mandibles 2/2 or 2/3 dentate, teeth blunt to hardly recognizable, dorsal tooth, if visible, minute. Mesosoma mostly yellow except pronotum pale brown medially and anterior margin of midlobe of mesoscutum sometimes pale brown, rarely axillae and metasoma more extensively pale brown. Mesosoma with hexagonally areolate sculpture dorsally; midlobe with 4–5 pairs of setae, posterior and lateral setae noticably stouter than medial setae, side lobe with 3 pairs (rarely with additional seta), axilla with 2 pairs (lateral pair minute), and scutellum 2 pairs, medial pair lateral to sensillae. Scutellar sensillae ovoid and separated by less than than their own maximum diameter; median groove narrow and distinct. Apical spur of mid tibia 0.7–0.9× as long as basitarsus; basitarsomere of midtarsus with 4–5 large pegs, tarsomeres 3–5 each with 1 robust apical peg, rarely a single peg on tarsomere 2. Tarsal formula 5–5–5. Fore wing 2.44–2.67× as long as broad, marginal fringe 0.13–0.29× width of fore wing; disc uniformly setose; costal cell with row of 13–23 small setae and 1–3 long marginal setae apically; submarginal vein with 2 large setae, basal area with 8–12 setae posterior to submarginal vein; frenal fold without spines; wing hyaline. Metasoma mostly yellow, tergites I + II sometimes with faint infuscation, usually yellow; laterally with weak cellulate reticulation; dorsal setal formula from tergite III: 2-2-2-6-6-6. Ovipositor 1.56–1.97× as long as mid tibia, 2.43–3.26× as long as clava, 0.8–0.9× as long as metasoma (base to tip of third valvula); third valvula elongate, 2.9–4.7× as long as broad, extruded beyond epygium, yellow except for extreme tip dark brown.

Male.—Overall coloration pale brown, darker brown pattern on head and mesosoma similar to *E. bimaculata* female, gaster entirely brown. Setation pattern of mesosoma and metasoma as in female but midlobe of mesoscutum with 4–5 pairs of setae. Midbasitarsomere with only 2 pegs. Antenna with 5 flagellomeres, apical two flagellomeres (5&6) fused, with segments distinguished only by a break in the pattern of linearia (Fig. 30).

Comments.—The Californian population differs from the Asian forms by having darkened axillae and gaster (yellow in asian forms) and the third valvulae less elongate, being less than 3.5× as long as broad. All females of *E. strenua* have at least 4 large pegs on the midbasitarsomere, a long ovipositor and third valvula, 8–12 setae in the basal area of the fore wing, and the tip of the third valvula brown. The males from India have a slightly more elongate antenna (ca. 1.2× as long as head width), whereas the single male has a slightly more compact antenna (ca. 1.1× as long as head width). The difference could be due to different mounting techniques, and for other characters the males were identical.

Hosts.—**Aleyrodidae**: *Aleurobus subrotundus* Silvestri (Clausen 1934), *Aleuroplatus* (Clausen 1934), *Asterochilton* (Clausen 1934), *Bemisia giffardii* (Kotinsky) (Silvestri 1928), *Dialeurodes citri* (Ashmead) (Polaszek *et al*. 1992), *Dialeurodes kirkaldii* (Kotinsky) (Polaszek *et al*. 1992), *Parabemisia myricae* (Kuwana) and *Siphonius phillyreae* (Haliday). The host records from Clausen (1934) have not been verified. The host range presented here is more restricted than that of Polaszek *et al*. (1992) after exclusion of much of the New World material now placed as *E. protransvena*.

Distribution.—**Nearctic**: USA (California). **Oriental**: China (Fujian, Guangdong) (Huang & Polaszek 1998); Hong Kong (Polaszek *et al*. 1992); India; Macau (Silvestri 1928).

Material Examined (60 females, 40 males).—**Hong Kong**: Kowloon, 2.xii.1986, F. Bennett, ex Jasmine whitefly on *Jasminium* (1♀ 1♂ USNM, 1♀ BMNH). **India**: Uttar Pradesh: Ranikhet, 4.viii, 7.viii, 18–19.viii, 11.ix, 10.ix, 7.x.1969, G. Chamora, R69-81, R69-85, R69-89, R69-101, R69-103, *D. citri* on *Citrus* (8♀ 24♂ UCRC); West Bengal: Kalimpang, 2.ix, 12.ix, 18.ix.1969, Kurup (CIBC), R69-98, R69-104, 69-106, R69-116, *Dialeurodes citri* on *Citrus* (43♀ 21♂ UCRC); Kayala: Bakarkhola [locality not verified], 21.vii.1969, G. Chondra, R69-77 (3♀ UCRC); [locality?] R69-93 (37♂ UCRC). **P.R. China**: Guangdong: Guangzhou, 11.vii.1992, F. Bennett Y941, *Dialeurodes* on *Citrus* (1♀ USNM). **Israel?** [no locality, just Tel-Aviv University header]: viii.1990, D. Gerling, on leaf with *Siphonius phyllireae* (2♀ USNM).

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